PHILADELPHIA UNIVERSITY FACULTY OF ENGINEERING

Department of Electrical Engineering

Course Title: Electrical Installation. **Prerequisite: Electrical Machines. (650321)**

Text Book: The design for electrical services of building, By : F porges,3rd Edition ,Taylor and France publishers ,2003,UK. ISBN 0-203-47308-6 Master e-book ISBN .

Semester: Second 2013/2014 **Instructor: Dr. Mohammed Tawfeeq**

Course Goals:

To introduce basic strictures of electrical installation distribution, equipments and materials.

Time Schedule:

Duration: 16 weeks **Lectures:** 3 hours / week

Objectives:

At completing this module the student should be able to:

1- Know of regulation of electrical installation systems.
2- Design and calculation of low voltage installations for buildings.
3- Have an idea about the protection and grounding .

Course Contents		
		Week
❖	**Introduction to electrical installation:** Wiring Regulations, Competence and responsibility, Procedure, Material, Design drawings, Voltage and voltage drop.	2
❖	**Electrical installation accessories :** Switches, Socket outlets ,Fused connection units, Boxes ,Lampholders , Ceiling roses etc.	1
❖	**Cables and wires :** Conductors, Insulation ,Sheathing , Type of cables , Cable laying methods , Wires , Volt-drops in cables and wires., PVC sheathed cable , XLPE cables, MICC External wiring Cable.	3
❖	**Wiring**: Conduit Plastic conduit, Cable trunking , Plastic trunking ,Metal conduit.	1
❖	**Illumination:** Lamps , Standards, Type of lighting and luminaires , Illumination technology, Methods of illumination calculation.	4
❖	**Load estimations :** Power calculations, Load factor ,Diversity factor, Circuits , Distribution boards.	2
❖	**Protection** : Rewirable fuses, H.R.C. fuses, M.C.B., MCCB ,RCD, R.C.C.B, Earthing systems.	2
❖	**Electronic and communication systems:** Fire alarm systems , Telephony systems , CCTV etc.	1

Mode of Assessment		
1	**First Exam**	**20%**
2	**Second Exam**	**20%**
3	**Reports\Homeworks\ and or Projects**	**20%**
4	**Final Exam**	**40%**

References

1.Electrical installation calculations Volume 1 A. J. Watkins and Chris Kitcher,Seventh edition . Elsevier publishers UK ,2006 ISBN–13 978-0-7506-6782.

2. Electrical installation calculations Volume 2 A. J. Watkins and Chris Kitcher,Seventh edition . Elsevier publishers UK ,2006 ISBN–13 978-0-7506-6782.

Electrical Installation

1. Introduction

Electrical installation describes the general aspects of electrical wiring as used to provide power in buildings and structures .

Electrical codes and standards

Wiring safety codes are intended to protect people and property from electrical shock and fire hazards. Regulations may be established by state or national legislation, produced by a technical standards-setting organization, or by a national standard electrical code. The cod gives design rules for electrical installations. The following cods are now applicable in many countries:

- In European countries, an attempt has been made to harmonize national wiring standards in an IEC standard, IEC 60364 Electrical Installations for Buildings. Hence national standards follow an identical system of sections and chapters.
- In the United Kingdom, wiring installations are regulated by the Institution of Engineering and Technology Requirements for Electrical Installations: IEE Wiring Regulations, BS 7671: 2008, which are harmonised with IEC 60364. The 17th edition (issued in January 2008) includes new sections for microgeneration and solar photovoltaic systems. The first edition was published in 1882.
- In Germany, DKE (the German Commission for Electrical, Electronic and Information Technologies of DIN and VDE) is the organisation responsible for the promulgation of electrical standards and safety specifications. DIN VDE 0100 is the German wiring regulations document harmonised with IEC 60364.
- In USA the US National Fire Protection Association, a private non-profit association formed by insurance companies, has published the National Electrical Code (NEC). States, counties or cities often include the NEC in their local building codes by reference along with local differences. The NEC is modified every three years. The proposals are studied by committees of engineers, tradesmen, manufacturer representatives, fire fighters, and others.

- In Jordan, the national Jordanian construction code centre has issued in 2008, the electrical installation code ,which is the same as the British IEE Wiring Regulations, BS 7671 .

كودات البناء الوطني الأردني – كودة التركيبات الكهربائية

- Arab code of electrical installation – Damascus, 2005.

الكود العربي للتمديدات الكهربائية – دمشق 2005 .

The international electric code: IEC 60364

IEC 60364 *Electrical Installations for Buildings* is the International Electrotechnical Commission's international standard on *electrical installations of buildings*. This standard is an attempt to harmonize national wiring standards in an IEC standard. The latest versions of many European wiring regulations (e.g., BS 7671 in the UK) follow the section structure of IEC 60364 very closely, but contain additional language to cater for historic national practice and to simplify field use and determination of compliance by electrical tradesmen and inspectors. National codes and site guides are meant to attain the common objectives of IEC 60364, and provide rules in a form that allows for guidance of persons installing and inspecting electrical systems.

The standard has several parts:

- Part 1: Fundamental principles, assessment of general characteristics, definitions
- Part 4: Protection for safety
  - Section 41: Protection against electric shock
  - Section 42: Protection against thermal effects
  - Section 43: Protection against overcurrent
  - Section 44: Protection against voltage disturbances and electromagnetic disturbances
- Part 5: Selection and erection of electrical equipment
  - Section 51: Common rules
  - Section 52: Wiring systems
  - Section 53: Isolation, switching and control
  - Section 54: Earthing arrangements, protective conductors and protective bonding conductors
  - Section 55: Other equipment
  - Section 56: Safety services

- Part 6: Verification
- Part 7: Requirements for special installations or locations
    - Section 701: Electrical installations in bathrooms
    - Section 702: Swimming pools and other basins
    - Section 703: Rooms and cabins containing sauna heaters
    - Section 704: Construction and demolition site installations
    - Section 705: Electrical installations of agricultural and horticultural premises
    - Section 706: Restrictive conductive locations
    - Section 708: Electrical installations in caravan parks and caravans
    - Section 709: Marinas and pleasure craft
    - Section 710: Medical locations
    - Section 712: Solar photovoltaic (PV) power supply systems
    - Section 713: Furniture
    - Section 714: External lighting
    - Section 715: Extra-low-voltage lighting installations
    - Section 717: Mobile or transportable units
    - Section 740: Temporary electrical installations for structures, amusement devices and booths at fairgrounds, amusement parks and circuses

Terminology

The Wiring Regulations carry a list of definitions for words and expressions which may not accord with standard dictionary definitions. Wherever there is any doubt, the Wiring Regulations definition should be applied.

Competence and responsibility

Any person involved with the installation of wiring in buildings takes on both legal and moral responsibilities for safety. A high level of technical and practical competence is essential. This can only be achieved with the appropriate study.

There are always three components to an electrical installation project:

- Design,
- Installation,
- Inspection and test.

Procedures

Design

It is sometimes thought that the use of tried and tested methods removes the design aspect from a scheme. This is not the case. Every project involves electrotechnical design decisions which are not to be confused with architectural or customer instructions for the physical location of electrical equipment. Thus, a self-employed electrical contractor who makes a decision on the selection and connection of an electrical accessory is a designer. The same applies to an electrician who makes a similar decision on behalf of an employer.

All technical design information must be recorded. This is a Wiring
514–09 Regulations requirement. IEE guidance is that it is essential to prepare a full specification prior to commencement or alteration of an electrical installation. The size and content of the specification will correspond with the complexity of the work. For simple jobs a few lines may suffice.

The designs shown in the following chapters are for guidance and each one includes a suggestion for a suitable design specification. A person selecting this guidance makes a design decision and therefore becomes the responsible person.

742–02 Upon completion of the contract the designer certifies that the design work is in accordance with the Wiring Regulations.

Installation

Where a technical design is drawn up by an electrical engineer or other competent person, it should not be the installer's job to check design details, unless this is one of the contract requirements. The installer is always under an obligation to point out to the designer any obvious conflict with regulations or standards and an installer should always refuse to carry out substandard work.

The installer has the responsibility to ensure that equipment is installed correctly and in accordance with the specification, supplemented by manufacturers' information. The installer is often delegated other tasks such as that of negotiating with the electricity supply company and verifying local licensing requirements.

Upon completion of the project, the installer certifies that the installation work has been carried out in accordance with the Wiring Regulations.

Inspection and test

No matter how simple or straightforward the job, test procedures must be carried out both during the course of the work and upon completion. This
711–01 applies equally to work carried out by a single self-employed operator. Self-certification is normally acceptable provided that the contractor has the competence and equipment to test correctly. The customer or an insurer may require specialist certification. This applies more particularly in the case of safety alarm systems or work in hazardous areas.

Whether an in-house or independent specialist, the inspector must be given the full design documentation with amendments showing any relevant on-site modifications. On larger projects this will include 'as fitted' drawings.

Certain parts of the installation may be hidden from view upon completion. In such cases the inspector must arrange for inspection during the course of erection or receive certified confirmation that the work is satisfactory.

Upon completion of the project, the inspector certifies that the inspection
741–01 and test have been carried out in accordance with the Wiring Regulations.

Completion

The signatures of the designer, installer and inspector are required for the
742–02 Electrical Installation Certificate. This cannot be issued until the work has been completed in accordance with the Wiring Regulations. Where there are acceptable departures from the Regulations, these must be shown on the certificate.

Materials

The Regulations require that every item of equipment shall comply with a
511–01 British Standard or harmonized European Standard. Alternatively, equipment complying with a relevant foreign standard may be used provided that the designer confirms that the equipment provides a degree of safety acceptable to the Regulations. This may mean product certification by an approvals organization.

2. Wiring materials and methods

Materials for wiring interior electrical systems in buildings vary depending on:

- Intended use and amount of power demand on the circuit
- Type of occupancy and size of the building
- National and local regulations
- Environment in which the wiring must operate.

Wiring systems in a single family home or flat, for example, are simple, with relatively low power requirements.

In a light commercial environment , large apparatus may be installed, and special conditions of heat or moisture may apply.

Heavy industries have more demanding wiring requirements, such as very large currents and higher voltages.

In facilities that handle flammable gases or liquids, special rules may govern the installation and wiring of electrical equipment in hazardous areas.

Wires and cables

Wires and cables are the main part of electrical installation. The rated by the circuit voltage, temperature rating, and environmental conditions in which they can be used.

A wire or cable has a voltage (to neutral) rating, and a maximum conductor surface temperature rating. The amount of current a cable or wire can safely carry depends on the installation conditions.

Early wires and cables

- **PI** : Paper-insulated cable is introduced in the United Kingdom in 1896, consisted of two impregnated-paper-insulated conductors in an overall lead sheath. These cables were similar to underground

telegraph and telephone cables of the time. Paper-insulated cables proved unsuitable for interior wiring installations because very careful workmanship was required on the lead sheaths to ensure moisture did not affect the insulation.

- **VIR** : In 1908 vulcanized-rubber insulated wire (**VIR**) enclosed in a strip metal sheath. The metal sheath was bonded to each metal wiring device to ensure earthing continuity.
- **TRS** : In the 1930 s' Tough rubber insulated or sheathed wire (**TRS**) were used for most electrical installation for buildings. Over time, rubber-insulated wires and cables become brittle because of exposure to atmospheric oxygen, so they must be handled with care, and are usually replaced during renovations . Hence Rubber insulation is no longer used for permanent wiring installations, but may still be used for replaceable temporary cables where flexibility is important, such as electrical extension cords.
- **PVC** : About 1950, **PVC** (poly vinyl chloride) insulation and jackets were introduced, especially for residential wiring. About the same time, single conductors with a thinner **PVC** insulation and a thin nylon jacket became common. The simplest form of cable has two insulated conductors twisted together to form a unit; such unjacketed cables with two or three conductors are used for low-voltage signal and control applications, see Fig.1.

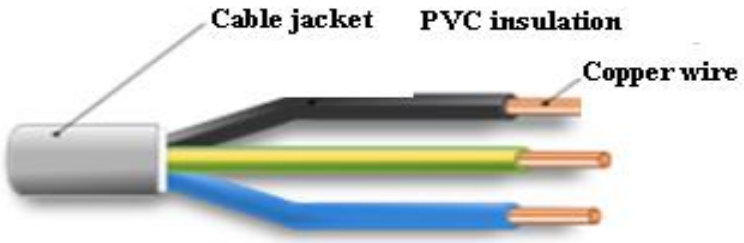


Fig.1 PVC insulated wire or cable with three pvc insulated conductors.

Copper conductors : *Copper wire and cable*

Electrical devices often contain copper conductors because of their multiple beneficial properties, including:

- high electrical conductivity,

- high tensile strength,
- high ductility,
- corrosion resistance,
- good thermal conductivity,
- solderability,
- resistance to electrical overloads,
- compatibility with electrical insulators, and
- ease of installation.

Despite competition from other materials, copper remains the preferred electrical conductor in nearly all categories of electrical wiring.

Aluminium conductors: *Aluminium wires and cables*

Aluminium wire was common in some countries residential wiring from the late 1960s to mid-1970s due to the rising cost of copper. Because of its greater resistivity, aluminium wiring requires larger conductors than copper.

Aluminium conductors were originally used with wiring devices intended for copper conductors. This practice was found to cause defective connections unless the aluminium was one of a special alloy, or all devices — breakers, switches, receptacles, splice connectors, wire nuts, etc. were specially designed for the purpose.

Aluminium conductors are still used for bulk power distribution and large feeder circuits, because they cost less than copper wiring, and weigh less, especially in the large sizes needed for heavy current loads. Aluminium conductors must be installed with compatible connectors.

Modern wiring materials

- Modern non-metallic sheathed cables, such as Types pvc / pvc and NYY (Germen) cables, consist of two to four wires covered with thermoplastic insulation, plus a bare wire for grounding (bonding), surrounded by a flexible plastic jacket.
- Special versions of non-metallic sheathed cables, such as Type pvc insulated pvc sheathed, are designed for direct underground burial (often with separate mechanical protection) or exterior use where exposure to ultraviolet radiation (UV) is a possibility. These

cables differ in having a moisture-resistant construction, lacking paper or other absorbent fillers, and being formulated for UV resistance.

- Rubber-like synthetic polymer insulation is used in industrial cables and power cables installed underground because of its superior moisture resistance.
- Generally, single conductor building wire in small sizes is solid wire, since the wiring is not required to be very flexible. Building wire conductors larger than 6 mm² (10 AWG) are stranded for flexibility during installation, but are not sufficiently pliable to use as appliance cord.
- Cables for industrial, commercial, and apartment buildings may contain many insulated conductors in an overall jacket, with helical tape steel or aluminium armour **AWA**, or steel wire armour **SWA**, and perhaps as well an overall PVC or lead jacket for protection from moisture and physical damage.
- Another form of high-temperature cable is a mineral insulated cable **MICC**, with individual conductors placed within a copper tube, and the space filled with magnesium oxide powder. The whole assembly is drawn down to smaller sizes, thereby compressing the powder. Such cables have a certified fire resistance rating, and are more costly than non-fire rated cable. They have little flexibility and behave more like rigid conduit rather than flexible cables.

Raceways or electrical conduits

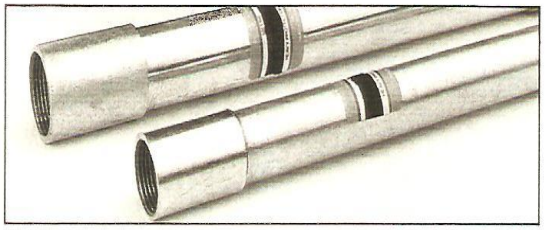
Electrical Conduit and Raceways are used to protect cables from damage. Insulated wires may be run in one of several forms of a raceway between electrical devices. This may be a specialized bendable pipe, called a conduit .

Types of condut

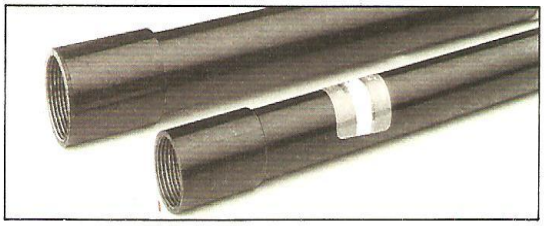
!. Metal conduit (rigid galvanized steel or Black Enameled Steel conduit),see Fig.1.

2. Non-metallic (PVC or HDPE) tubing (piping), see Fig.2.

3. Rectangular cross-section metal or PVC wire or trunking (UK) may be used if many circuits are required, see Fig.3.



Galvanized steel Conduit



Black Enameled Steel conduit

Fig.1 Metal conduit

Fig.2 Non-metallic (PVC or HDPE) pipes

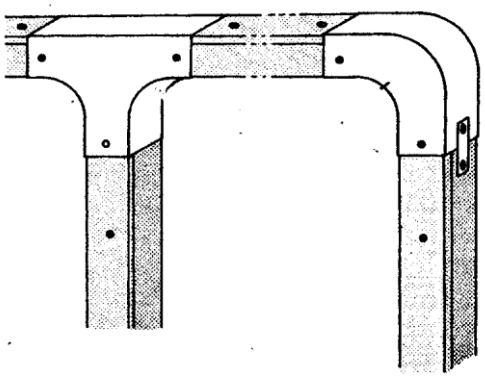
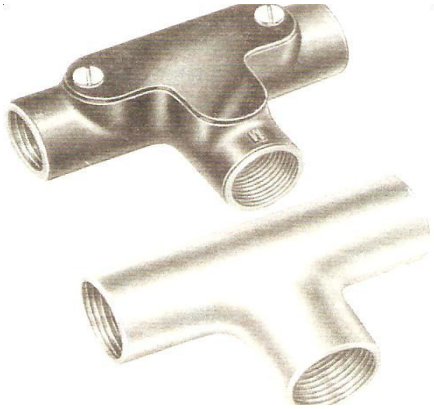


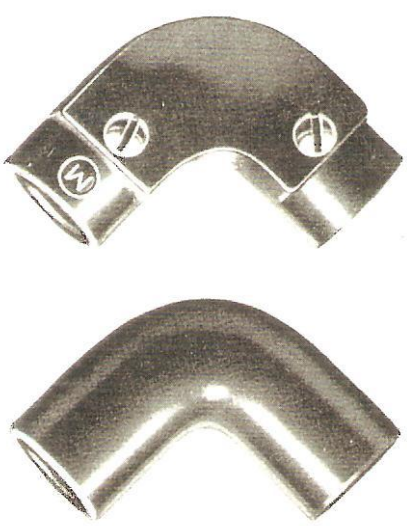
Fig.3 Rectangular cross-section metal or PVC wire or **trunking**.

Wires run underground may be run in plastic tubing encased in concrete, but metal elbows may be used in severe pulls.

Conduit accessories: Metal conduit accessories are:



TEES

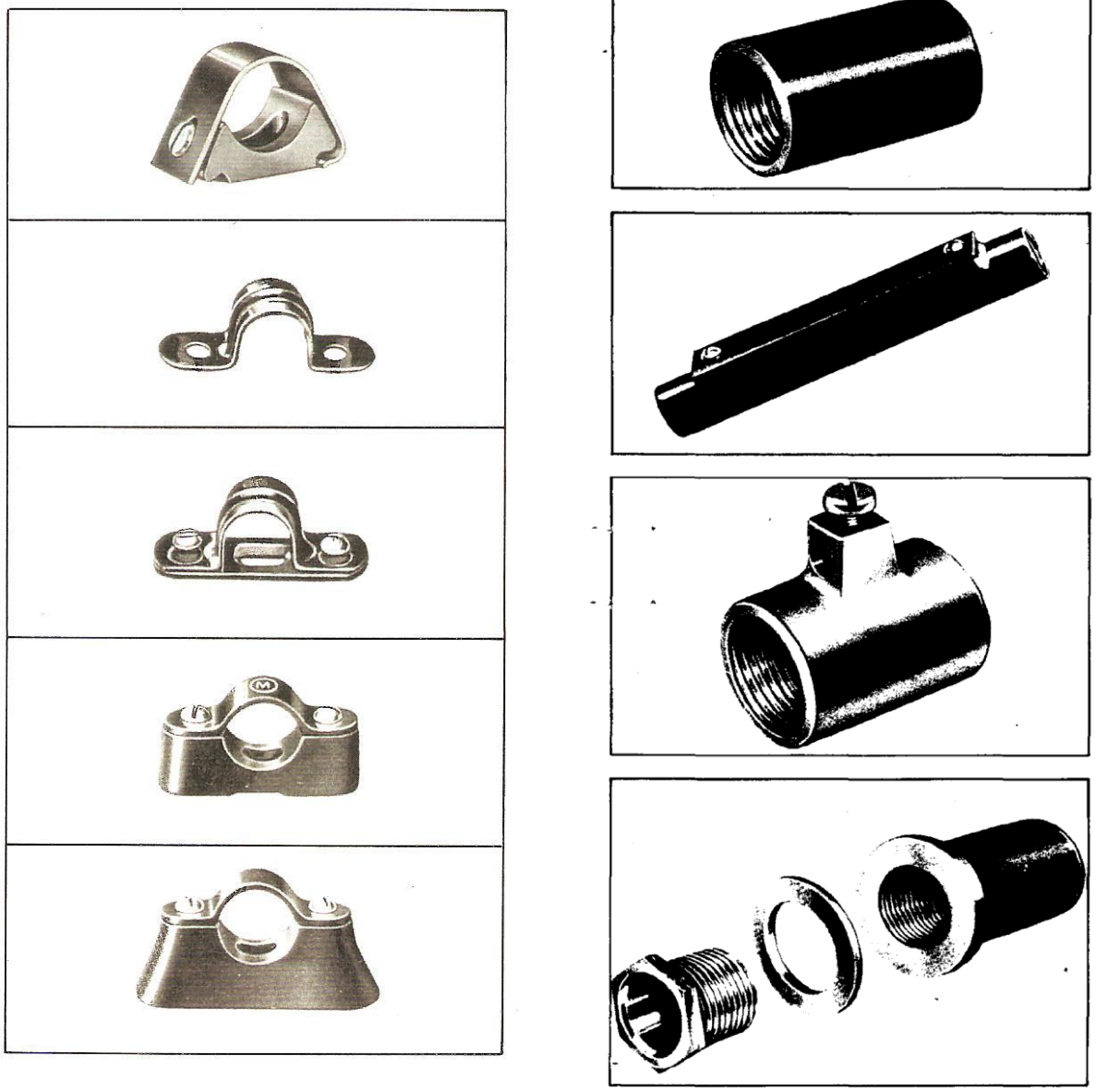


ELBOWS & BENDS

HOOK

BOXES

Fig.4 Conduit accessories.



SADDLES CNNECTORS

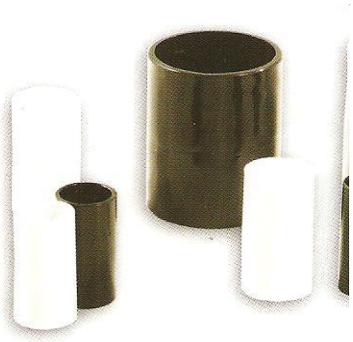
Fig.5 Conduit accessories.

PVC Pipes accessories

JUNCTIONS

ELBOWS

ADDAPTERS



CONNECTORS

BOXES

SADDLES

Fig.6 PVC accessories.

Cable trays

Wiring in exposed areas, for example factory floors, may be run in cable trays or rectangular raceways having lids.

Cable trays are used in industrial areas where many insulated cables are run together. Individual cables can exit the tray at any point, simplifying the wiring installation and reducing the labour cost for installing new cables. Power cables may have fittings in the tray to maintain clearance between the conductors, but small control wiring is often installed without any intentional spacing between cables.

Since wires run in conduits or underground cannot dissipate heat as easily as in open air, and since adjacent circuits contribute induced currents, wiring regulations give rules to establish the current capacity (ampacity).

Special sealed fittings are used for wiring routed through potentially explosive atmospheres.

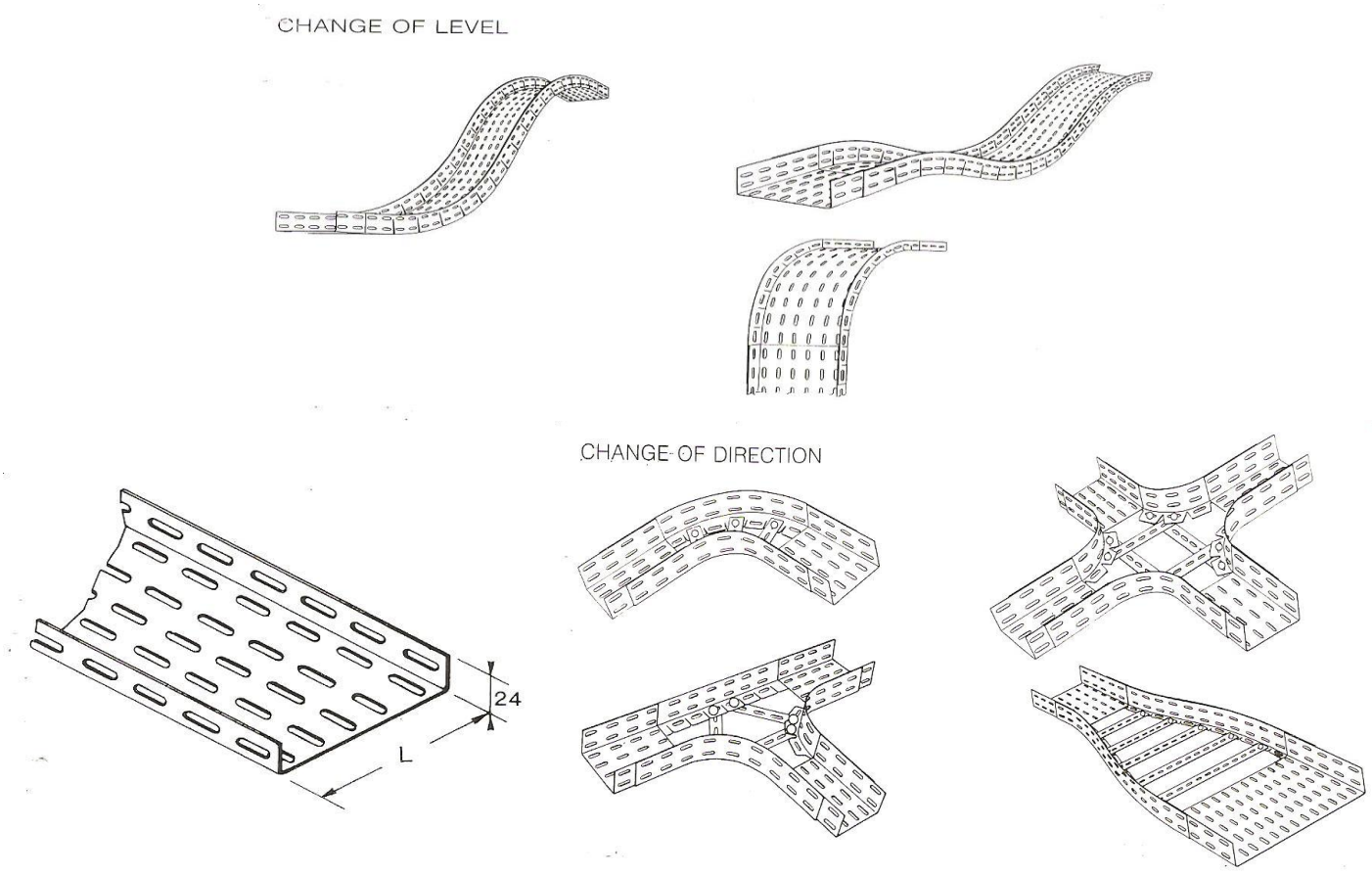


Fig.7 Cable trays.

Current carrying capacity tables of cables and wires according to IEC standard (Arabian Code)

الجدول (5-3) سعات نقل التيار بالأمبير حسب طريقة التركيب المحددة في الجدول (4-3) عازل PVC نحاس أو ألمنيوم لناقلين (موصلين) محملين درجة حرارة الناقل : 70 مئوية ، درجة الحرارة المحيطية : 30 مئوية في الهواء ، 20 مئوية في الأرض

بالنسبة للكيبلات مدفونة تحت الارض بتربة ذات مقاومية حرارية 2.5 كلفن . م \ واط

المقطع الاسمي للناقل مم^2	طرائق التركيب في الجدول(4-3)					
	A1	A2	B1	B2	C	D
1	2	3	4	5	6	7
نحاس						تحت الارض
1.5	14.5	14	17.5	16.5	19.5	22
2.5	19.5	18.5	24	23	27	29
4	26	25	32	30	36	38
6	34	32	41	38	46	47
10	46	43	57	52	63	63
16	61	57	76	69	85	81
25	80	75	101	90	112	104
35	99	92	125	111	138	125
50	119	110	151	133	168	148
70	151	139	192	168	213	183
95	182	167	232	201	258	216
120	210	192	269	232	299	246
150	240	219	-	-	344	278
185	273	248	-	-	392	312
240	321	291	-	-	461	361
300	367	334	-	-	530	408
ألمنيوم						
2.5	15	14.5	18.5	17.5	18.5	22
4	20	19.5	25	24	25	29
6	26	25	32	30	32	36
10	36	33	44	41	44	48
16	48	44	60	54	59	62
25	63	58	79	71	73	80
35	77	71	97	86	90	96
50	93	86	118	104	110	113
70	118	108	150	131	140	140
95	142	130	181	157	170	166
120	164	150	210	181	197	189
150	189	172	-	-	227	213
185	215	195	-	-	259	240
240	252	229	-	-	305	277
300	289	263	-	-	351	313

ملاحظة : الأعمدة 3 و5 و6 و7 متوافقة مع الكيبلات ذات النواقل الدائرية حتى المقطع 16 مم^2 . أما المقاسات الأكبر فهي للكيبلات غير الدائرية ويمكن تطبيقها على النواقل الدائرية .

الجدول (3-6) سعات نقل التيار بالأمبير حسب طريقة التركيب المحددة في الجدول (3-4) عزل EPRأو XLPE لناقلين(موصلين) محملين، نحاس أو ألمنيوم
درجة حرارة الناقل : 90 مئوية ، درجة الحرارة المحيطية : 30 مئوية في الهواء ، 20 مئوية في الأرض
بالنسبة للكيبلات مدفونة تحت الارض بتربة ذات مقاومية حرارية 2.5 كلفن . م \ واط

طرائق التركيب في الجدول (3-4)						المقطع الاسمي للناقل مم^2
D	C	B2	B1	A2	A1	
7	6	5	4	3	2	1
تحت الارض						نحاس
26	24	22	33	18.5	19	1.5
34	33	30	31	25	26	2.5
44	45	40	42	33	35	4
56	58	51	54	42	45	6
73	80	69	75	57	61	10
95	107	91	100	76	81	16
121	138	119	133	99	106	25
146	171	146	164	121	131	35
173	209	175	198	145	158	50
213	269	221	235	183	200	70
252	328	265	306	220	241	95
287	382	305	345	253	278	120
324	441	-	-	290	318	150
363	506	-	-	329	326	185
419	599	-	-	386	424	240
474	693	-	-	442	486	300
						المنيوم
26	26	23	25	19.5	20	2.5
34	35	31	33	26	27	4
42	45	40	43	33	35	6
56	62	54	59	45	48	10
73	84	72	79	60	64	16
93	101	94	105	78	84	25
112	126	115	130	96	103	35
132	154	183	157	115	125	50
163	198	175	200	145	158	70
193	241	210	242	175	191	95
220	280	242	281	201	220	120
249	324	-	-	230	253	150
279	371	-	-	262	228	185
322	439	-	-	307	338	240
364	508	-	-	352	387	300

ملاحظة : الأعمدة 3 و5 و6 و7 متوافقة مع الكيبلات ذات النواقل الدائرية حتى المقطع 16 مم ^{2}. أما المقاسات الأكبر فهي للكيبلات غير الدائرية ويمكن تطبيقها على النواقل الدائرية .

الجدول (3-7) سعات نقل التيار بالأمبير حسب طريقة التركيب المحددة في الجدول (3-4) عزل PVCثلاثة نواقل (موصلات) محملة ، نحاس أو ألمنيوم
درجة حرارة الناقل : 70 مئوية ، درجة الحرارة المحيطية : 30 مئوية في الهواء ، 20 مئوية في الأرض

بالنسبة للكيبلات مدفونة تحت الارض بتربة ذات مقاومية حرارية 2.5 كلفن . م \ واط

المقطع الاسمي للناقل مم^2	طرائق التركيب في الجدول (3-4)					
	A1	A2	B1	B2	C	D
1	2	3	4	5	6	7
نحاس						**تحت الارض**
1.5	13.5	13	15.5	15	17.5	18
2.5	18	17.5	21	20	24	24
4	24	23	28	27	32	31
6	31	29	36	43	41	39
10	42	39	50	46	57	52
16	56	52	68	62	76	67
25	73	68	89	80	96	86
35	89	83	110	99	119	103
50	108	99	134	118	144	122
70	136	125	171	149	184	151
95	164	150	207	179	223	179
120	188	172	239	206	259	203
150	216	196	-	-	399	230
185	245	223	-	-	341	258
240	286	261	-	-	403	297
300	328	298	-	-	464	336
ألمنيوم						
2.5	14	13.5	16.5	15.5	18.5	18.5
4	18.5	17.5	22	21	25	24
6	24	23	28	27	32	30
10	32	31	39	36	44	40
16	43	41	53	48	59	52
25	57	53	70	62	73	66
35	70	65	86	77	90	80
50	84	78	104	92	110	94
70	107	98	133	116	140	117
95	129	118	161	139	170	138
120	149	135	186	160	197	157
150	170	155	-	-	227	178
185	194	176	-	-	259	200
240	227	207	-	-	305	230
300	216	237	-	-	351	260

ملاحظة : الأعمدة 3،5،6،7 متوافقة مع الكيبلات ذات النواقل الدائرية حتى المقطع 16 مم^2 . أما المقاسات الأكبر فهي للكيبلات غير الدائرية ويمكن تطبيقها على النواقل الدائرية

الجدول (3-8) سعات نقل التيار بالأمبير حسب طريقة التركيب المحددة في الجدول (3-4) عزل XLPE أو EPR ،ثلاثة نواقل(موصلات) محملة ، نحاس أو ألمنيوم
درجة حرارة الناقل :90 درجة مئوية ، درجة الحرارة المحيطية : 30درجة مئوية في الهواء، 20 درجة مئوية في الأرض .
بالنسبة للكيبلات المدفونة تحت الارض ، التربة ذات مقاومية حرارية 2.5كلفن . م \ واط

المقطع الأساسي للناقل مم^2	طرائق التركيب في الجدول (3-4)					
	A1	A2	B1	B2	C	D تحت الارض
1	2	3	4	5	6	7
النحاس						
1.5	17	16.5	20	19.5	22	22
2.5	23	22	28	26	30	29
4	31	30	37	35	40	37
6	40	38	48	44	52	46
10	54	51	66	60	71	61
16	73	68	88	80	96	79
25	95	89	117	105	119	101
35	117	109	144	128	147	122
50	141	130	175	154	179	144
70	179	164	222	194	229	178
95	216	197	269	233	278	211
120	249	227	312	268	322	240
150	285	259	-	-	371	271
185	324	295	-	-	424	304
240	380	346	-	-	500	351
300	435	396	-	-	576	396
ألمنيوم						
2.5	19	18	22	21	24	22
4	25	24	29	28	32	29
6	32	31	38	35	41	36
10	44	41	52	48	57	47
16	58	55	71	64	76	61
25	76	71	93	84	90	78
35	94	87	116	103	112	94
50	113	104	140	124	136	112
70	142	131	179	156	174	138
95	171	157	217	188	211	164
120	197	180	251	216	245	186
150	226	206	-	-	283	210
185	256	233	-	-	323	236
240	300	273	-	-	382	272
300	344	313	-	-	440	308

ملاحظة : ألأعمدة 3، 5،6،7 متوافقة مع الكيبلات ذات النواقل حتى المقطع 16 ملم^2 . أما المقاسات الأكبر فهي للكيبلات غير الدائرية و يمكن تطبيقها على النواقل الدائرية .

الجدول (3-9) سعات نقل التيار بالأمبير لطريقة التركيب C (الكيبلات ممدودة في الهواء) في الجدول (3-4) نواقل(موصلات) نحاسية مغلفة ب PVC 600 / 1000 فولت .
درجة حرارة الناقل :70 درجة مئوية ، درجة الحرارة المحيطية المرجعية :30 درجة مئوية.

المقطع الأساسي للناقل مم^2	عدد النواقل و طريقة تركيبها - الطريقة C في الجدول (3-4)			
	كيبل وحيد الناقل	ثلاثة نواقل محملة		
		كيبل متعدد النواقل في تشكيلة ثلاثية أو رباعية	كيبلات وحيدة الناقل في تشكيلة ثلاثية	كيبلات وحيدة الناقل في تشكيلة مستقيمة
1	2	3	4	5
1.5	27	19	21	23
2.5	35	25	28	31
4	47	34	37	41
6	59	43	48	52
10	81	59	65	70
16	107	79	86	92
25	144	106	114	120
35	176	129	137	147
50	214	157	169	181
70	270	199	207	221
95	334	246	264	264
120	389	285	307	303
150	446	326	327	346
185	516	374	371	392
240	618	445	445	467
300	717	511	521	560
400	843	597	646	660
500	994	669	747	770

ملاحظة1: لكيبلات وحيدة الناقل يجب ربط الأغلفة لكل دائرة مع بعضها في كلتا النهايتين .
ملاحظة 2: بالنسبة للنواقل العارية المعرضة للمس يجب ضرب القيم بـ 0.9 .

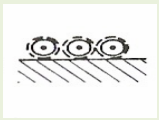
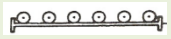
الجدول (10-3) سعات نقل التيار بالأمبير لطريقة التركيب C (الكيبلات ممدودة في الهواء) في الجدول (4-3) نواقل(موصلات) نحاسية مغلفة ب XLPE 600 / 1000 فولت .

درجة حرارة الناقل : 90 درجة مئوية ، درجة الحرارة المحيطية المرجعية :30 درجة مئوية.

المقطع الأساسي للناقل مم^2	عدد النواقل و طريقة تركيبها - الطريقة C في الجدول (4-3)		
	كيبل وحيد الناقل	ثلاثة نواقل محملة	
		كيبل متعدد النواقل في تشكيلة ثلاثية أو رباعية	كيبلات وحيدة الناقل في تشكيلة ثلاثية
1	2	3	4
1.5	33	24	26
2.5	43	32	34
4	57	42	44
6	72	54	56
10	99	74	77
16	131	98	102
25	177	133	138
35	217	162	170
50	265	197	207
70	336	250	263
95	415	308	325
120	485	359	380
150	557	412	437
185	646	457	507
240	774	564	604
300	901	649	696
400	1060	761	811
500	1252	866	940

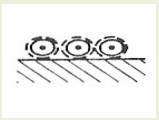
ملاحظة1: لكيبلات وحيدة الناقل يجب ربط الأغلفة لكل دائرة مع بعضها في كلتا النهايتين .
ملاحظة 2: بالنسبة للنواقل العارية المعرضة للمس يجب ضرب القيم بـ 0.9 .

جدول (11-3) سعات نقل التيار بالأمبير لطرائق التركيب E، F ،G من الجدول (4-3) عزل معدني (مسلحة)، نواقل(موصلات) نحاسية مغلفة ب PVC 600/ 1000 فولت
درجة حرارة الناقل :˚70 مئوية، درجة الحرارة المحيطة المرجعية :˚30 مئوية

المقطع الأساسي للناقل مم^2	عدد النواقل و طريقة تركيبها - الطرق E,G,F في الجدول (4-3)				
	ناقلان محملان مزدوجان أو وحيد الناقل طريقة E أو F	ثلاثة نواقل محملة			
		متعدد أو وحيد الناقل في تشكيلة ثلاثية طريقة E أوF	وحيد الناقل متلامس طريقة F	وحيد الناقل متباعد شاقوليا طريقة G	وحيد الناقل متباعدا أفقيا طريقة G
					
1	2	3	4	5	6
1.5	26	22	26	28	32
2.5	36	30	34	37	43
4	47	40	45	49	56
6	60	51	57	62	71
10	82	69	77	84	95
16	109	92	102	110	125
25	142	120	132	142	162
35	174	147	161	173	197
50	215	182	198	213	242
70	264	223	241	256	294
95	317	267	289	309	351
120	364	308	331	353	402
150	414	352	377	400	454
185	472	399	426	446	507
240	552	466	496	497	565

ملاحظة1: لكيبلات وحيدة الناقل يجب ربط الأغلفة لكل دائرة مع بعضها في كلتا النهايتين .
ملاحظة 2: بالنسبة للنواقل العارية المعرضة للمس يجب ضرب القيم بـ 0.9 .
ملاحظة 3 : dd= القطر الخارجي للكيبل .

جدول (3-12) سعات نقل التيار بالأمبير لطرائق التركيب E، F ،G من الجدول (3-4) عزل معدني (مسلحة)، نواقل (موصلات)نحاسية مغلفة بـ XLPE 600/ 1000 فولت ، درجة حرارة الناقل : 90 درجة مئوية، درجة الحرارة المحيطة المرجعية :30 درجة مئوية.

المقطع الأساسي للناقل $مم^2$	عدد النواقل و طريقة تركيبها - الطرق E,G,F في الجدول (3-2)				
	ناقلان محملان مزدوجان أو وحيد الناقل طريقة E أو F	ثلاثة نواقل محملة			
		متعدد أو وحيد الناقل في تشكيلة ثلاثية طريقة E أوF	وحيد الناقل متلامس طريقة F	وحيد الناقل متباعد شاقوليا طريقة G	وحيد الناقل متباعدا أفقيا طريقة G
					
1	2	3	4	5	6
1.5	33	24	32	34	40
2.5	43	32	38	44	51
4	57	42	51	59	68
6	72	53	65	74	85
10	99	74	90	101	115
16	131	98	118	132	150
25	177	133	160	177	200
35	217	162	197	215	246
50	265	197	238	262	298
70	336	250	302	325	374
95	415	308	373	402	460
120	485	359	437	470	536
150	557	412	500	540	610
185	646	475	581	626	694
240	774	564	697	750	792

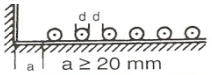
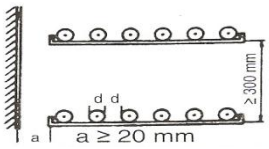
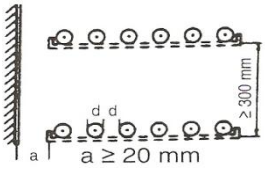
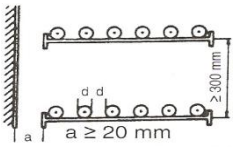
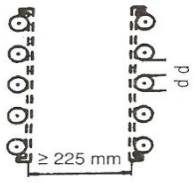
ملاحظة1: لكيبلات وحيدة الناقل يجب ربط الأغلفة لكل دائرة مع بعضها في كلا النهايتين .
ملاحظة 2: بالنسبة للنواقل العارية المعرضة للمس يجب ضرب القيم بـ 0.9 .
ملاحظة 3 : dd= القطر الخارجي للكيبل .

الجدول (3-13) عوامل تخفيض من أجل المجموعات التي تحتوي على أكثر من دارة أو كيبل مفردالناقل . يطبق هذا الجدول على سعات نقل التيار للجداول من (3-5) إلى (3-12) .

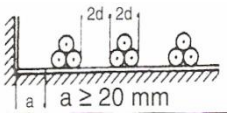
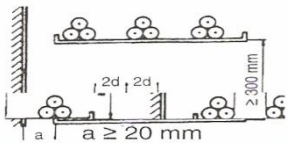
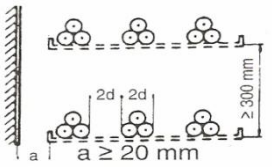
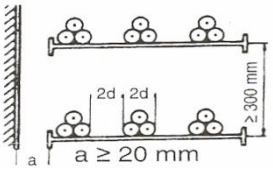
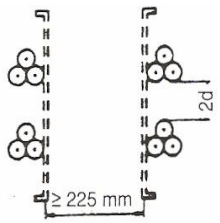
	الترتيب (كيبلات متلامسة)	1	2	4	5	7	8	9	12	16	20	يستعمل مع سعة نقل التيار المرجعية
1	محزوم على السطح أو ضمن مجرى أو قناة أو مدفون في الجدران	1.0	0.8	0.65	0.60	0.54	0.52	0.50	0.45	0.41	0.38	(3-5) إلى (3-12) للطرق A حتى F
2	طبقة واحدة على الجدار، الأرضية أو على حامل (صينية) غير مثقب	1.0	0.85	0.75	0.73	0.72	0.71	0.70	لا ضرورة لاستخدام عامل تخفيض لأكثر من تسعة دارات أو كابلات متعددة النواقل			(3-9) حتى (3-10) للطريقة C
3	طبقة واحدة مثبتة مباشرة فوق سقف خشبي	0.95	0.81	0.68	0.66	0.63	0.62	0.61				(3-11) حتى (3-12) للطرق FوE
4	طبقة واحدة على حامل مثقب أفقي أو شاقولي	1.00	0.88	0.77	0.75	0.73	0.72	0.72				
5	طبقة واحدة على سلم أو دعائم وغيرها	1.00	0.87	0.80	0.80	0.79	0.78	0.78				

ملاحظة : تعتبر التمديدات متجاورة إذا كان التباعد بين الكيبلين أقل من ضعف قطر الكيبل الأكبر.عندما يتم مد الكيبلات على أكثر من طبقة فإن عامل التصحيح أعلاه يجب أن يضرب بالعوامل التالية:
طبقتان : 0.8 ثلاث طبقات : 0.73 أربع أو خمس طبقات : 0.70

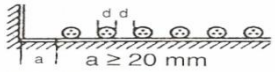
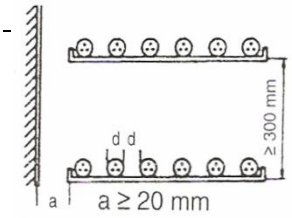
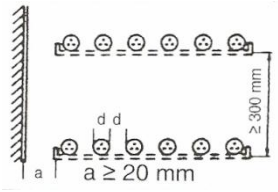
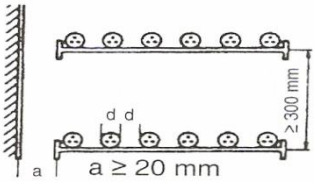
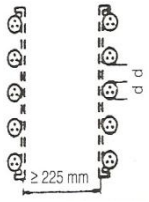
الجدول (14-3) عوامل التخفيض لأجل المجموعات لكيبلات وحيد ة الناقل (مفردة) ممدودة في الهواء ومتباعدة للمنظومات ثلاثية الطور حسب نشرات شركة ABB.

1	2	3	4	5
التركيب بشكل مستوي بتباعد يساوي قطر الكيبل نفسه تقريبا (d)	**عدد الرفوف بالاتجاه الشاقولي**	**عدد الدارات في الاتجاه الافقي**		
		1	**2**	**3**
كيبلات ممدودة على الارضية 	1	0.92	0.89	0.88
حاملات كيبل غير مثقبة 	1	0.92	0.89	0.88
	2	0.87	0.84	0. 83
	3	0.84	0.82	0.81
	6	0.82	0.80	0.79
حاملات كيبل مثقبة 	1	1.00	0.93	0.90
	2	0.97	0.89	0. 85
	3	0.96	0.88	0.82
	6	0.94	0.85	0.80
مساند كيبلات Cable Racks 	1	1.00	0.97	0.96
	2	0.97	0.94	0.93
	3	0.96	0.93	0.92
	6	0.94	0.91	0.90
على مساند كيبلات 	1	0.94	0.91	0.89
أو على الجدار أو على حاملات كيبل مثقبة شاقوليا	2	0.94	0.90	0.86

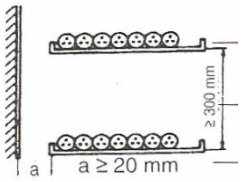
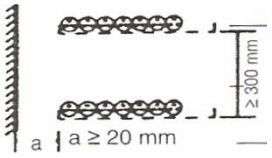
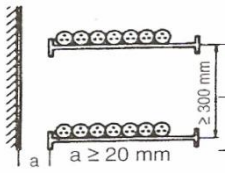
الجدول (15-3) عوامل التخفيض لأجل المجموعات لكيبلات وحيد ة الناقل (مفردة) ممدودة في الهواء على شكل مجاميع ثلاثية (Trefoil) في المنظومات ثلاثية الطور حسب نشرات شركة ABB.

1	2	3	4	5
التركيب بشكل مثلثي بتباعد يساوي قطر الكيبل نفسه تقريبا (d)	**عدد الرفوف بالاتجاه الشاقولي**	**عدد الدارات**	**في الاتجاه الافقي**	
		1	**2**	**3**
كيبلات ممدودة على الارضية 	1	0.98	0.96	0.94
حاملات كيبل غير مثقبة 	1	0.98	0.96	0.94
	2	0.95	0.91	0.87
	3	0.94	0.90	0.85
	6	0.93	0.88	0.82
حاملات كيبل مثقبة 	1	1.00	0.98	0.96
	2	0.97	0.93	0. 89
	3	0.96	0.92	0.85
	6	0.94	0.90	0.83
مساند كيبلات Cable Racks 	1	1.00	0.97	0.96
	2	0.97	0.95	0.93
	3	0.96	0.94	0.90
	6	0.95	0.93	0.87
على مساند كيبلات أو على الجدار أو على حاملات كيبل مثقبة شاقوليا 	1	1.00	0.91	0.89
	2	1.00	0.90	0.86

الجدول (16-3) عوامل التخفيض لأجل المجموعات لكيبلات ثلاثية الطور ممدودة في الهواء- متباعدة حسب نشرات شركة ABB .

1	2	3	4	5	6	7
التركيب بتباعد يساوي قطر الكيبل نفسه تقريبا (d)	**عدد الرفوف بالاتجاه الشاقولي**	**عدد الكيبلات في الاتجاه الافقي**				
		1	**2**	**3**	**4**	**6**
كيبلات ممدودة على الارضية 	1	0.97	0.85	0.78	0.75	0.71
حاملات كيبل غير مثقبة 	1	0.97	0.96	0.94	0.93	0.90
	2	0.97	0.95	0. 92	0.90	0.86
	3	0.97	0.94	0.91	0.89	0.84
	6	0.97	0.93	0.90	0.88	0.83
حاملات كيبل مثقبة 	1	1.00	1.00	0.98	0.95	0.91
	2	1.00	0.99	0.96	0.92	0.87
	3	1.00	0.98	0.95	0.91	0.85
	6	1.00	0.97	0.94	0.90	0.84
مساند كيبلات Cable Racks 	1	1.00	1.00	1.00	1.00	1.00
	2	1.00	0.99	0.98	0.97	0.96
	3	1.00	0.98	0.97	0.96	0.93
	6	1.00	0.97	0.96	0.94	0.91
على مساند كيبلات  أو على الجدار أو على حاملات كيبل مثقبة شاقوليا	1	1.00	0.91	0.89	0.88	0.87
	2	1.00	0.91	0.88	0.87	0.85

الجدول (3-17) عوامل التخفيض لأجل المجموعات لكيبلات ثلاثية الطور ممدودة في الهواء - متجاورة حسب نشرات شركة ABB .

1	2	3	4	5	6	7	8
التركيب متجاورة ومتلاصقة	**عدد الرفوف بالاتجاه الشاقولي**	**عدد الكيبلات في الاتجاه الافقي**					
		1	**2**	**3**	**4**	**6**	**9**
كيبلات ممدودة على الارضية	1	0.97	0.96	0.94	0.93	0.90	0.68
حاملات كيبل غير مثقبة 	1	0.97	0.85	0.78	0.75	0.71	0.68
	2	0.97	0.84	0.76	0.73	0.68	0.63
	3	0.97	0.83	0.75	0.72	0.66	0.63
	6	0.97	0.81	0.73	0.69	0.63	0.58
حاملات كيبل مثقبة 	1	1.00	0.88	0.82	0.79	0.76	0.73
	2	1.00	0.87	0.80	0.77	0.73	0.68
	3	1.00	0.86	0.79	0.76	0.71	0.66
	6	1.00	0.84	0.77	0.73	0.68	0.64
مساند كيبلات Cable Racks 	1	1.00	0.87	0.82	0.80	0.79	0.78
	2	1.00	0.86	0.80	0.78	0.76	0.73
	3	1.00	0.85	0.79	0.76	0.73	0.70
	6	1.00	0.83	0.76	0.73	0.69	0.66
على مساند كيبلات أو على الجدار أو على حاملا مثقبة شاقوليا	1	1.00	0.88	0.82	0.78	0.73	0.72
	2	1.00	0.88	0.81	0.76	0.71	0.70

الجدول (3-18) عوامل التصحيح من أجل درجات حرارة الهواء المحيط المختلفة عن 30° مئوية تطبق على سعات نقل التيار للكيبلات في الهواء .

درجة حرارة المحيط مئوية	العـــــــــــزل		
	PVC	EPR أوXLPE	معدني* مغطى بـ PVC أو عاري معرض للمس 30^0 مئوية
10	1.22	1.15	1.26
15	1.17	1.12	1.20
20	1.12	1.08	1.14
25	1.06	1.04	1.07
35	0.94	0.96	0.93
40	0.87	0.91	0.85
45	0.79	0.87	0.77
50	0.71	0.82	0.67
55	0.61	0.76	0.57
60	0.50	0.71	0.45
65	-	0.65	-
70	-	0.58	-
75	-	0.50	-
80	-	0.41	-
85	-	-	-
90	-	-	-
95	-	-	-

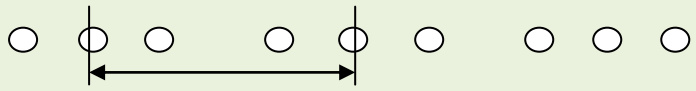
*** بالنسبة لدرجات حرارة الجو الأعلى من ذلك يجب استشارة الشركة الصانعة**

الجدول (3- 19) عامل عمق الدفن للكيبلات المطمورة تحت الأرض Direct in ground أوالموضوعة في خنادق مباشرة Direct in ducts .

كيبلات ممدودة مباشرة في الأرض		كيبلات ممدودة داخل خنادق		
عمق الدفن(متر)	عامل التقنين لحد 300 ملم^2	عامل التقنين لأعلى من 300 ملم^2	عامل التقنين (ناقل واحد)	عامل التقنين (ثلاثة نواقل)
0.80	1.0	1.0	1.0	1.0
1.0	0.98	0.97	0.98	0.99
1.25	0.96	0.95	0.95	0.97
1.50	0.95	0.93	0.94	0.96
1.75	0.94	0.91	0.92	0.96
2	0.92	0.89	0.91	0.95
2.5	0.91	088	0.89	0.94
3	0.90	0.86	0.88	0.93

الجدول (3-20) عامل المجموعات للكيبلات المطمورة تحت الأرض Direct in ground وفقا للتباعد Spacing بالمتر.

كيبلات وحيدة الناقل (مفردة) موضوعة بشكل أفقي ضمن منظومات ثلاثية الطور



عدد الدارات	تباعد الدارات بالمتر			
	0.15	0.30	0.45	0.6
2	0.80	0.84	0.87	0.89
3	0.69	0.75	0.79	0.82
4	0.63	0.70	0.75	0.79
5	0.59	0.66	0.72	0.76
6	0.56	0.64	0.70	0.74
7	0.53	0.62	0.68	0.73
8	0.52	0.60	0.67	0.72
9	0.50	0.59	0.66	0.71
10	0.49	0.58	0.65	0.71
11	0.48	0.57	0.65	0.70
12	0.47	0.57	0.64	0.70

الجدول (3-21) عامل المجموعات للكيبلات المطمورة تحت الأرض Direct in ground وفقا للتباعد Spacing بالمتر

كيبلات وحيدة الناقل (مفردة) موضوعة بشكل مثلثي Trefoil أو بشكل أفقي متلاسقة ثلاثية الطور	تباعد الدارات ـ متر				
0 (مثلثي Trefoil)	0 (مد أفقي Laid flat)	0.15	0.30	0.45	0.60
0.78	0.80	0.82	0.86	0.89	0.91
0.66	0.68	0.71	0.77	0.80	0.83
0.59	0.62	0.65	0.78	0.77	0.80
0.55	0.58	0.61	0.68	0.74	078
0.52	0.55	0.58	0.66	0.72	0.76
0.49	0.52	0.56	0.64	0.70	0.75
0.47	0.50	0.54	0.63	0.69	0.74
0.45	0.48	0.52	0.61	0.68	0.74
0.44	0.47	0.51	0.61	0.68	0.73
0.43	0.46	0.50	0.0.6	0.67	0.73
0.41	0.45	0.49	0.59	0.67	0.72

الجدول (3-22) عامل المجموعات للكيبلات المطمورة تحت الأرض وفقا لمسافة تباعدها بالمتر.

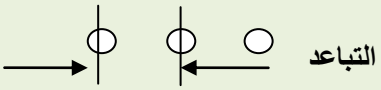
كيبلات ثلاثية الناقل Three Core Cables ممدودة مباشرة تحت الأرض بصورة أفقية 					
عدد الكيبلات في المجموعة	مسافة التباعد بالمتر				
	0.00	**0.15**	**0.30**	**0.45**	**0.6**
2	0.80	0.85	0.89	0.91	0.93
3	0.68	0.76	0.81	0.84	0.87
4	0.62	0.71	0.77	0.81	0.84
5	0.57	0.66	0.73	0.78	0.82
6	0.54	0.64	0.71	0.77	0.81
7	0.51	0.61	0.69	0.75	0.79
8	0.49	0.59	0.68	0.74	0.79
9	0.47	0.58	0.67	0.73	078
10	0.45	0.57	0.66	0.73	0.78
11	0.44	0.55	0.65	0.72	0.77
12	0.43	0.54	0.64	0.77	0.77

Table: 3-23 Electrical properties for cables

Electrical properties for cables الخواص الكهربائية للكيبلات			
أعلى تيار قصر دورة متماثل Isc (kA)	هبوط الفولتية ملي فولت/ أمبير / متر	الممانعة أوم/ كيلومتر	قياس الكيبل بالملمتر المربع
Short circuit rating (kA)Isc	Volt drop (mV/A/m)	Impedance (Ω/km)	Cable size (mm2)
0.17	25.080	14.48	1.5
0.28	15.363	8.87	2.5
0.46	9.561	5.52	4
0.69	6.391	3.69	6
1.15	3.793	2.19	10
1.84	2.390	1.38	16
2.87	1.515	0.8749	25
4.02	1.097	0.6335	35
5.75	0.817	0.4718	50
8.05	0.576	0.3325	70
10.92	0.427	0.2460	95
13.80	0.348	0.2012	120
17.25	0.294	0.1698	150
21.60	0.250	0.1445	185
27.60	0.211	0.1220	240
34.50	0.140	0.1090	300

ملاحظة : وضع هذا الجدول للكيبلات النحاسية بعزل PVC محسوبا لدرجة حرارة 30 مئوية.ذ

Bus bars, bus duct, cable bus and cables

- Bus bar

For very heavy currents in electrical apparatus, and for heavy currents distributed through a building, bus bars can be used. Each live conductor of such a system is a rigid piece of copper or aluminium, usually in flat bars.

In industrial applications, conductor bars are often pre-assembled with insulators in grounded enclosures. This assembly, known as bus duct or busway, can be used for connections to large switchgear or for bringing the main power feed into a building. A form of bus duct known as "plug-in bus" is used to distribute power down the length of a building; it is constructed to allow tap-off switches or motor controllers to be installed at designated places along the bus. The big advantage of this scheme is the ability to remove or add a branch circuit without removing voltage from the whole duct.

Busbars for distributing PE (ground)

Bus ducts may have all phase conductors in the same enclosure (non-isolated bus), or may have each conductor separated by a grounded barrier from the adjacent phases (segregated bus). For conducting large currents between devices, a cable bus is used.

Standard wire colours for fixed cable

European Union (EU) (IEC 60446) including UK from 31 March 2004 (BS 7671)

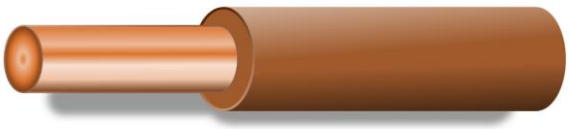
Table: 3-1

Conductor colour identification

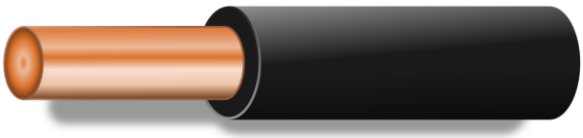
	Old colour	*New colour*	*Marking*
Phase 1 of a.c.	Red	Brown	L1
Phase 2 of a.c.	Yellow	Black	L2
Phase 3 of a.c.	Blue	Grey	L3
Neutral of a.c.	Black	Blue	N

Note Great care must be taken when working on installations containing old and new colours.

Phase1- Brown



Phase 2 - Black



Phase3- Gray

Neutral - Blue

Earth – Green yellow

UK prior to 31 March 2004 (BS 7671)

L1

L2

L3

Neutral wire

Earth wire

Space factor

Any cables installed into a trunking or duct should not use more than 45% of the available space (cross-sectional area) within the trunking or duct. This is called the space factor.

EXAMPLE 1 Calculate the amount of usable area within a trunking 50 mm by 75 mm.

Solution :

Cross-sectional area of trunking can be found 50 × 75 = 3750 mm

Space factor = $\frac{3750 \times 45}{100} = 1687.5 \text{ mm}^2.$

.

This is the amount of space that can be used. When calculating how many cables can be installed in the trunking , it is important to take into account the insulation around the cable as this counts as used space.

Table 3- 2 : Details of single core thermoplastic (pvc) cables

Nominal conductor size (mm^2)	*Number and diameter of wires (no. of strands × mm^2)*	*Nominal overall diameter (mm)*
1.0	1 × 1.13	2.9
1.5	1 × 1.38	3.1
2.5	1 × 1.78	3.5
2.5 (stranded)	7.067	3.8
4	7 × 0.85	4.3
6	7 × 1.04	4.9
10	7 × 1.35	6.2
16	7 × 1.70	7.3
25	7 × 2.14	9.0
35	19 × 1.53	10.3
50	19 × 1.78	12.0

EXAMPLE 2 Calculate the maximum number of 10 mm^2 cables that could be installed in a 50 mm × 75 mm trunking allowing for space factor.
Find area of trunking 50 × 75 = 3750 mm^2
Usable area 3750 × 45 % = 1687.50

or

$$\text{or } \frac{3750 \times 45}{100} = 1687.50\,\text{mm}^2$$

From Table A, the diameter of a 10 mm^2 cable is 6.2 mm. The cross-sectional area (csa) of one cable is

$$\frac{\pi d^2}{4} = \frac{3.142 \times 6.2^2}{4} = 30.19\,\text{mm}^2$$

To calculate the number of cables that it would be permissible to install in the trunking.

$$\frac{\text{Usable area}}{\text{csa of cable}} = \text{Number of cables}$$

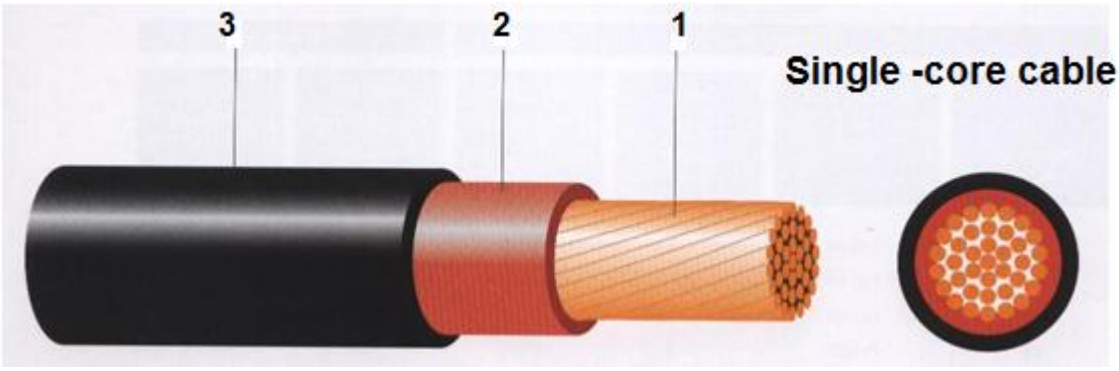
$$\frac{1687.5}{30.19} = 55.89, \quad \text{therefore 55 cables can be installed.}$$

Electrical Power Cables

Types of power cables:

- Low Voltage Cables
- Medium and High Voltage Cables
- Control ,Signal and Instrumentation Cables

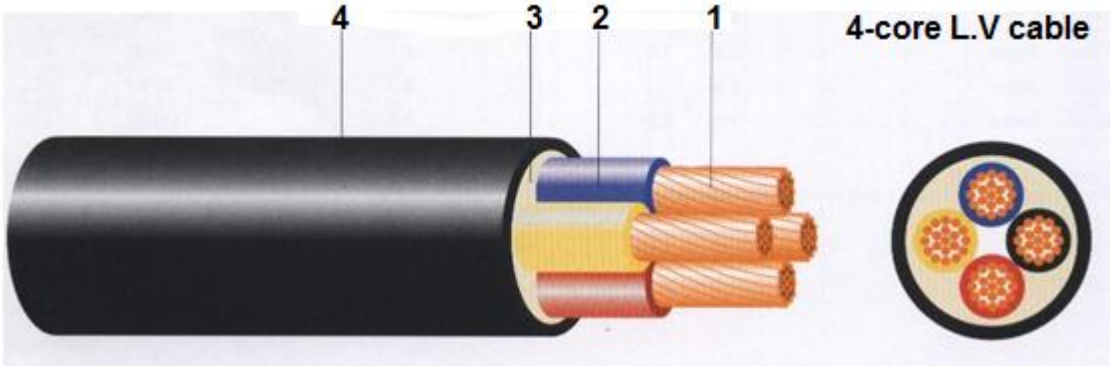
Cables are manufactured in single – core, 2-core, 3-core, 4-core and 5-core.



1- Copper or aluminium conductor (stranded)

2- PVC insulation

3- PVC sheathed



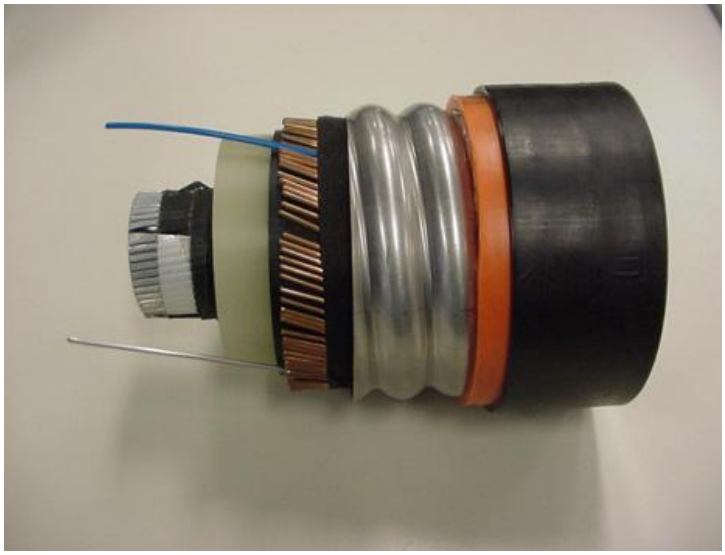
1- Copper or aluminium conductor (stranded)

2- PVC insulation

3- Extruded jacket

4- PVC sheathed

Cables with voltage ratings more than 1000 V must be armoured according to IEC regulation. A high voltage cable armoured with steel wires and metal tape (double armoured) is shown in the following figure.



H.V. Armoured cable

Type of cables

The type of cable depends on its insulation type, generally, there are the following insulations used to manufacture the cables:

- PVC: Insulating compound based on polyvinyl chloride or copolymer of vinyl chloride. بلاستك كلوريد متعدد الفنيل
- PE: Insulating compound based on thermo plastic polyethylene. بلاستك متعدد الاثلين
- Butyl Rubber: Insulating compound based on ethylene propylene rubber or similar. مطاط بيوتيل او مايشابهه
- EPR: Insulating compound based on ethylene propylene rubber or similar (EPM or EPDM). مركب اثلين بروبلين أو مايشابهه

- XLPE: Insulating compound based on chemically cross-linked polyethylene. متعدد الاثلين المربوط بالتصالب (التشابكي)
- XLPO: Insulating compound based on chemically Cross-linked polyolefin. متعدد الاولفين المربوط بالتصالب (التشابكي)
- Paper: Paper-insulating cable. العزل بالورق

Each type of cable can operate in its own temperature designed for. The following table3 –3gives the limit or maximum operating temperature for each type of cable.

Table : 3-3

Maximum operating temperature for the conductor in ^{o}C.	Type of Insulation
70	PVC
90	XLPE
90-80	EPR and EPDM
90	XLPO
100	Butyl Rubber

Cable Rating (Current carrying capacity)

An important part of any electrical design is the determination of the size of cables. The size of cable to be used in a given circuit is governed by the current which the circuit has to carry, so the design problem is to decide the size of cable needed to carry a known current.

Tables have been prepared and published which list the maximum allowable current for each type and size of cable. The tables give a current rating for each type and size of cable for a particular method of installation and at a particular ambient temperature.

For these basic conditions a cable must be chosen the rated current of which is at least equal to the working current. For other methods of installation and ambient temperatures the tables give various correction factors. The actual working current has to be divided by these to give a nominal current and a cable then selected such that its rated current is at least equal to this nominal current.

Wiring system installation methods (According to IEC regulation)

the determination of the type and disposition of the installation circuits. Table -3-4 gives details of commonly installed wiring systems and cable types. Having made the choice of system and cable type, the next stage is to determine the design current.

Symbols

The symbols used in this context are generally aligned with those used in BS 7671 together with some additional symbols which have been found necessary.

C Correction symbols used infrequently are defined where they occur in the text.

C_a factor for ambient temperature

C_d correction factor for type of overcurrent protective device

C_d = 1 for HBC fuses and mcbs

C_d = 0.725 for semi-enclosed fuses

C_g correction factor for grouping

C_i correction factor for conductors embedded in thermal insulation

C_r correction factor for grouping of ring circuits

l circuit route length, m

I_b design current of circuit, A

$I_{\Delta n}$ rated residual operating current of an rcd, mA or A

I_n nominal current of protective device, A

I_{ef} earth fault current, A

I_{sc} short circuit current, A

I_t required tabulated current-carrying capacity, A

I_{ta} actual tabulated current-carrying capacity, A

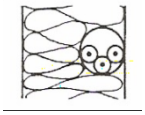
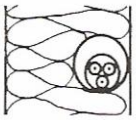
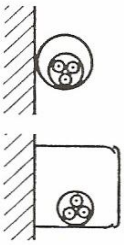
I_x current used as a basis for calculating the required current-carrying capacity of the live conductors, A

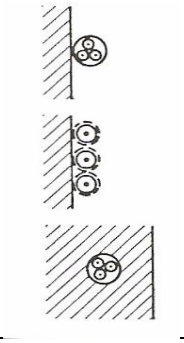
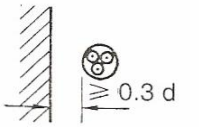
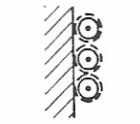
I_z effective current-carrying capacity, A

S conductor cross-sectional area, mm
t_a actual or expected ambient temperature, °C
t_o maximum permitted conductor temperature under overload conditions, °C

Note : The IEC standard uses letter K instead of C for correction factors.

Table : 3-4 Wiring system installation methods (IEC Standard)

Description	Method
Single – core cables embedded in conduits or pipes in walls 	**A_1**
Multi – core cable embedded in conduits or pipes in walls 	**A_2**
Single-core non-sheathed cables in electrical ducts or conduits **Laying on walls or under plaster.** **(including ventilated floor ducts)**	**B_1**
Laying on walls **Multicore non-sheathed cables in electrical ducts or conduits** **on the wall or floor** 	**B_2**

Direct wall fixing by cleats or staples or on cable trays 	**C**
Direct buried in the ground	**D**
Laying exposed in air, i.e. thermal dissipation is ensured without hindrance where the lines are installed > 0.3 d from the wall ,d = external diameter of the line with lines installed above one another with a vertical spacing of a minimum of twice the line diameter 	**E**
Laying exposed in air, i.e. thermal dissipation is ensured without hindrance with lines installed side by side spaced at a minimum of twice the line diameter (as E above) 	**F**
Laying exposed in air, i.e. thermal dissipation is ensured without hindrance with lines installed above one another with a vertical or horizental spacing of minimum of twice the line diameter.	**G**

Calculation of the Cross-sectional Areas of Circuit Live Conductors and Cables

- Voltages

All specifications, design and calculations should use 230/400V voltage figures when the supply comes directly from the main. However if the supply comes from consumer local substation then 240/415 V figure is used.

The factors that influence the current rating of any cable are:

1. The design current – the cable must carry the full load current;
2. The type of cable – PVC, XLPE,, copper conductors or aluminium conductors;
3. The installed conditions – clipped to a surface or installed with other cables in a trucking;
4. The surrounding temperature – cable resistance increases as temperature increases and insulation may melt if the temperature is too high;
5. The type of protection – for how long will the cable have to carry a fault current?

- Allowable Voltage drops in the cables:

Regulation states that the drop in voltage from the supply terminals to the fixed current-using equipment must not exceed 3% for lighting circuits and 5% for other uses of the mains voltage. That is, a maximum of 6.9 V for lighting circuits and 11.5 V for other uses on a 230 V installation.

To determine the minimum conductor cross-sectional area of the live conductors of a particular circuit that can be tolerated the designer must:

(a) Determine the method of installation according to the standard table (3-4).

(b) Establish what is the expected ambient temperature (t_a ºC). This gives the relevant value of Ca (or K1).

(c) Decide whether the circuit is to be run singly or be bunched or grouped with other circuits and, how many other circuits. The decision taken gives the relevant value of C_g (or K2).

(d) Decide whether the circuit is likely to be totally surrounded by thermally insulating material . If this is to be the case, Ci (or K3) is taken to be 0.5.

(e) Determine the design current (I_b) of the circuit.

(f) Choose the type and nominal current rating (In) of the associated overcurrent protective device. For all cases In must be equal to or greater than Ib.

Establish whether it is intended the overcurrent protective device is to give:
(i) overload protection only, or
(ii) short circuit protection only, or
(iii) overload and short circuit protection.

The intended function of the overcurrent protective device not only determines
whether Ib or In is used as the basis for calculating the minimum cross sectional area of the live conductors but also influences the value of Ca that is to be used in the calculations.

(g) Establish the maximum voltage drop that can be tolerated.

(h) Estimate the route length of the circuit.

The general method for the determination of the minimum conductor cross sectional areas that can be tolerated now described does not apply to cables installed in enclosed trenches. These are considered later. The general method is as follows:

The cable rating, denoted I_t , may be determined as follows:

First calculate the current I_t where:

$$I_t = \frac{\text{Current rating of protective device}}{\text{Any applicable correction factors}}$$

$$I_t = I_x \times \frac{1}{C_a} \times \frac{1}{C_g} \times \frac{1}{C_i} \times \frac{1}{C_d} \text{ A}$$

C_a = the ambient or surrounding temperature correction factor,

.

C_g = the grouping correction factor.

.

C_d (or C_c) = the 0.725 correction factor to be applied when semi-enclosed fuses protect the circuit

C_i = the correction factor to be used when cables are enclosed in thermal insulation.

EXAMPLE 1: A 3 - core, copper conductor belted type XLPE cable has a cross sectional area of 240 mm^2. If four cables of this type are laid together on a perforated cable tray at 40 ºC ambient temperature, find the derating factor and the new current carrying capacity of the cable.

Solution:

- Determine the method of installation from Table (3-4) (Lecture No.3). ⟹ E
- Determine the current carrying capacity of the 240 mm2 XLPE cable from Table (3-12) for installation method E , this gives : I = 564 A at 30 ºC .
- Determine the grouping factor for four cables from Table (3-17) for method of installation E with number of trays =1 and number of cables = 4 ⟹ Cg = 0.79.
- Determine the correction factor for the difference in temperature (ambient temp .-40 ºC) from Table (3-18) ⟹ Ca = 0.91 .
- Calculate the correction factor :

$$C = Ca \,.Cg = 0.91 \times 0.79 = 0.718$$

= Derating factor

Hence the new current carrying capacity of the cable will be:

$$I_t = 564 \times C = 564 \times 0.718 = 405 \text{ A}$$

EXAMPLE 2 : A circuit is to be installed using 3x 2.5 mm^2 (twin and earth) 70°C PVC cable, it is 32 metres long and protected by a BS 88 fuse. The load to be supplied is a 4.2 kW hot water cylinder; the circuit is to be installed in minitrunking containing one other circuit at an ambient temperature of 35°C. Maximum permissible volt drop is 7 V. Calculate the minimum cable that may be used.

Solution
Design current

$$I_b = \frac{P}{V}$$

$$\frac{4.2 \times 1000}{230} = 18.26 \text{ amperes}$$

Protective device $I_n \ (\geq 18.26)$

nearest protective device rating is 20 amperes.

In the example, the cable is installed in plastic trunking. From Table 3- 4 Installation methods, B1 and B2 matches the example. The cable is installed in trunking which will contain one other circuit. Correction factor for grouping (C_g *or* K_2) is required from Table(3-13). It can be seen that for two circuits in one enclosure a factor of 0.8 must be used.

The ambient temperature is 35°C. A correction factor for ambient temperature (C_a) from Table (3-18) must be used. PVC cable at 35 , C_a factor of 0.94.
Using these factors, it is now possible to calculate the minimum size conductors required for this circuit.

$$I_t \geq \frac{I_n}{C_a \times C_g}$$

$$I_t \geq \frac{20}{0.8 \times 0.94} = 26.59 \text{ A}$$

- This is the minimum value of current that the cable must be able to carry. From Table (3-5) columns 4 and 5, it can be seen that a 4mm^2 cable has an I_t (current carrying capacity) of 30 amperes.

- A cable with 4mm^2 live conductors will carry the current in these conditions without overheating, but will it comply with the voltage drop requirements?

From Table (3-23) columns 1 and 3, it can be seen that 4 mm^2 cable has a voltage drop of 9.56 (mV/A/m) or millivolts × loadcurrent × length of circuit. As the value is in millivolts, it must be converted to volts by dividing by 1000. The circuit length is 32 metres and the load current is 18.26 amperes.

Calculation

$$\frac{mV/A/m \times I \times L}{1000} = \frac{9.56 \times 18.26 \times 32}{1000} = 5.57 \text{ V}$$

The voltage drop in this cable will be 6.42 V which is acceptable as the maximum permissible for the circuit is 7 V.

Calculation of the Cross-sectional Areas of Circuit Live Conductors and Cables Considering Overcurrent protection of the cables

Overcurrent can be subdivided into overload current, and short circuit current.

- Overload
  This is caused when too many appliances are connected on the circuit or applying excessive mechanical load on a machine.
- Fault
  This is caused when failure of insulation occurs.

1.Overload protection

An overload may result in currents of two or three times the rated current flowing in the circuit.

A protective device must be used to break overload current before any thermal damage is done to cable insulation. The selected protective device should have a current rating which is not less than the full load current of the circuit I_b but which does not exceed the cable current rating I_z. This can be explained as follows:

- The nominal rating of the protective device:
  Greater than the design current of the circuit and less than the operational current of the cable conductor.

$$I_b < I_n < I_z$$

- The operating current must not exceed : $1.45 \times I_t$

The cable is then fully protected against both overload and short-circuit faults.

Note : The above overload protection may not be applied for the cases when the load is such that is not likely to be overloaded such as a fixed lighting systems.

2. Fault or Overcurrent protection

Fault current is usually caused by short circuit faults due to the failure of cable insulation or between two live conductors of the system or any other reasons.

The initial surge current may exceeds thousand of amperes (kA) and need to be disconnected very fast. The short circuit level in the circuit will decide the short circuit rating of the protective device.

When selecting a protective device we must give consideration to the following factors:

The prospective fault current.
The circuit load characteristics.
The current carrying capacity of the cable.
The disconnection time requirements for the circuit.

Protective Devices

Devices which provide overcurrent protection are:

- Fuses

1- *Semi-enclosed fuses:* These were previously called rewirable fuses and are used mainly on domestic installations having a maximum fault capacity of about 4 kA. (*BS 3036*

2- *Cartridge fuses:* These are used for a.c. circuits on industrial and domestic installations having a fault capacity of about 16 kA to 30 kA.(*BS 1361& BS 1362*

3- HBC (or HRC) fuses: High Breaking Capacity or High rupturing Capacity are used for industrial applications having a maximum fault capacity of 80 kA. (*BS 88-6 or* BS 88 'gG')

These fuses are shown in Fig.1 and 2.

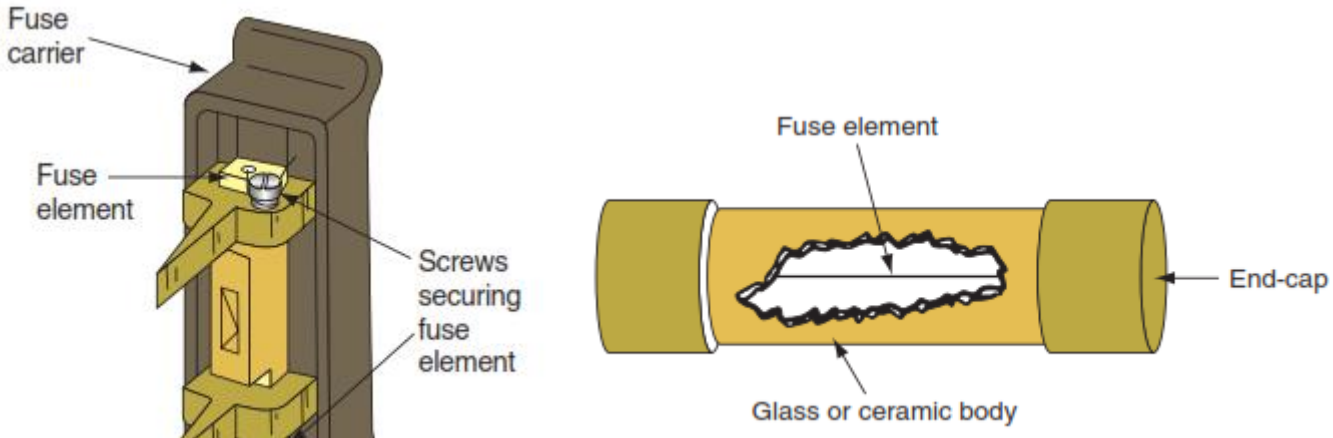


Fig. 1

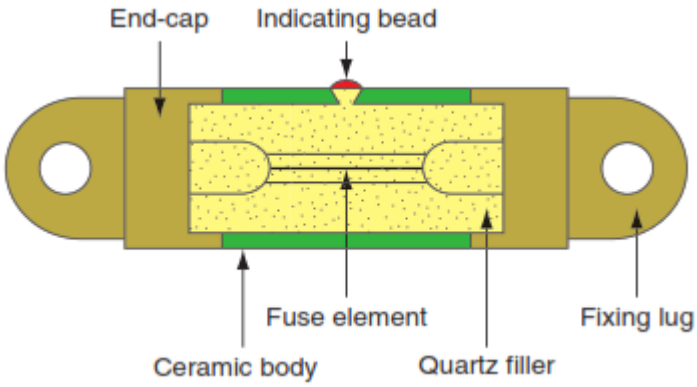


Fig. 2 HBC fuse.

- Circuit Breakers

Miniature circuit breakers (MCBs): These are MCBs which may be used as an alternative to fuses for some installations. The Standards includes ratings up to 100 A and maximum fault capacities of 9kA. They are graded according to their instantaneous tripping currents –that is, the current at which they will trip within 100 ms.
Types of MCBs :

- *MCB Type B: This type* will trip instantly between three and five times its rated current and is also suitable for domestic and commercial installations.(*BS EN 60898)*

(I_m = above $3I_n$ up to and including $5I_n$)

- *MCB Type C: This type* will trip instantly between five and ten times its rated current. It is more suitable for highly inductive commercial and industrial loads.(*BS EN 60898)*

(I_m = above $5I_n$ up to and including $10I_n$)

- *MCB Type D: This type* will trip instantly between 10 and 20 times its rated current. It is suitable for welding and X-ray machines where large inrush currents may occur.(*BS EN 60898)*

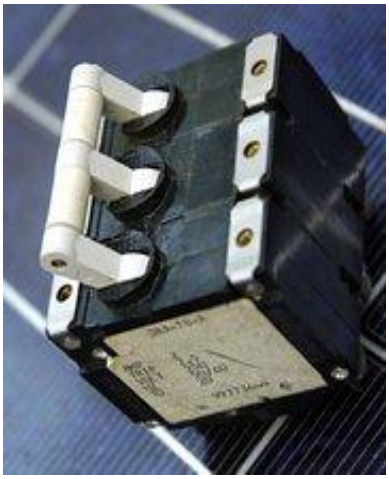
(I_m = above 10 I_n up to and including 20 I_n)

Where I_n = Normal (rated) current
I_m = Magnetic releases operating current range of the MCB.

MCB Construction

1. Actuator lever - used to manually trip and reset the circuit breaker. Also indicates the status of the circuit breaker (On or Off/tripped). Most breakers are designed so they can still trip even if the lever is held or locked in the on position. This is sometimes referred to as "free trip" or "positive trip" operation.
2. Actuator mechanism - forces the contacts together or apart.
3. Contacts - Allow current to flow when touching and break the flow of current when moved apart.
4. Terminals
5. Bimetallic strip
6. Calibration screw - allows the manufacturer to precisely adjust the trip current of the device after assembly.
7. Solenoid
8. Arc divider / extinguisher

Single- pole MCBs



Three – pole MCB.

Doble – pole MCB.

The commonly-available preferred values for the rated current are 6 A, 10 A, 13 A, 16 A, 20 A, 25 A, 32 A, 40 A, 50 A, 63 A, 80 A and 100 A

Fig.3 Miniature circuit breakers MCBs.

An MCB of the type shown in Fig.3 incorporates a thermal and magnetic tripping device. The load current flows through the thermal and the electromagnetic mechanisms. In normal operation the current is insufficient to operate either device, but when an overload occurs, the bimetal strip heats up, bends and trips the mechanism. The time taken for this action to occur provides an MCB with the ability to discriminate between an overload which persists for a very short time, for example the starting current of a motor, and an overload due to a fault.

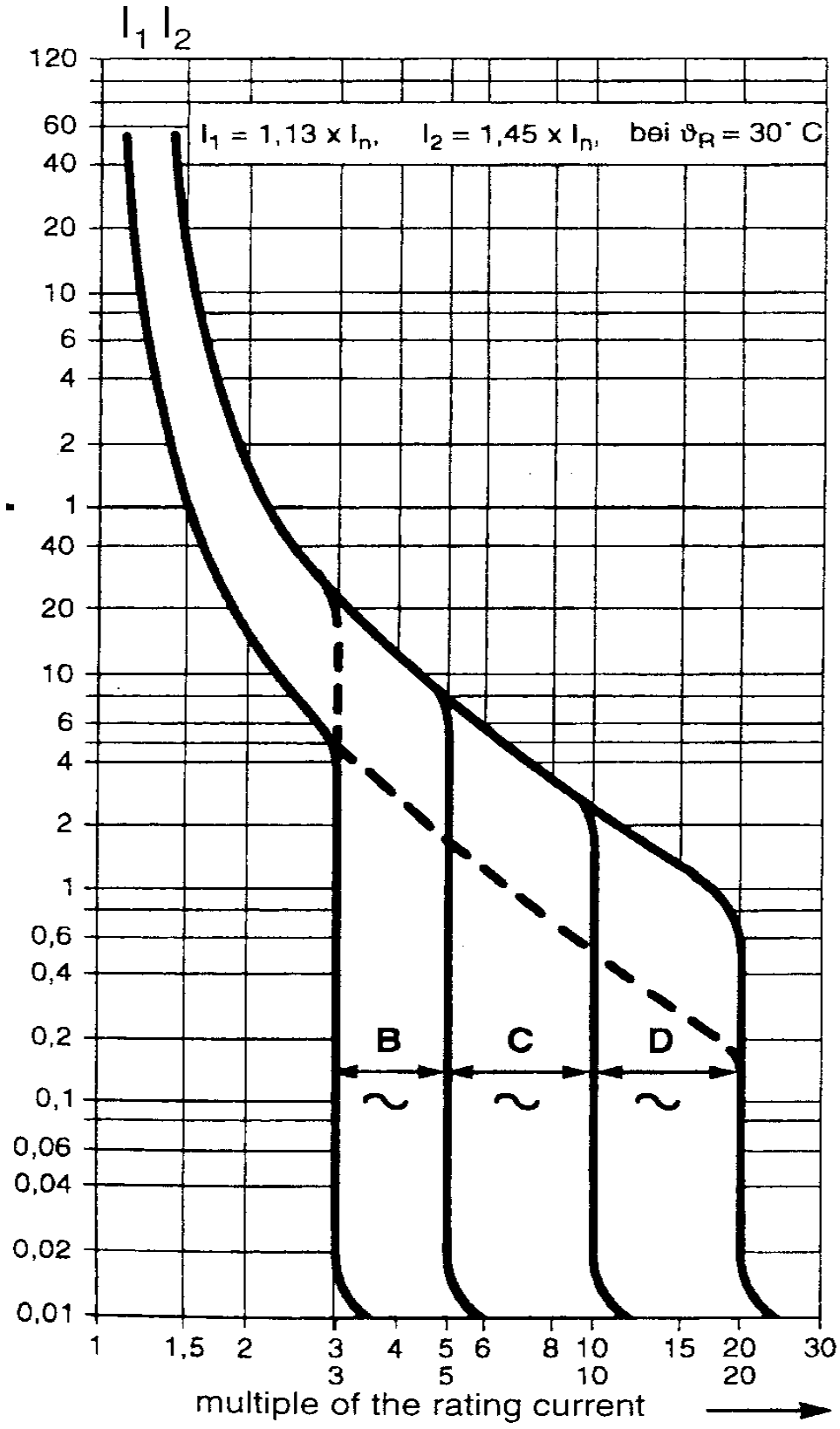


Fig. 4 MCB characteristics.

Example 1
A d.c. circuit has a design current of 28 A. It is to be wired in a two-core EPR cable having 85ºC rubber insulation and copper conductors. It is to be installed in trucking with five other similar circuits.
If t_a= 40ºC and the circuit is to be protected by a 45 A HBC fuse to BS 1361 against short circuit faults only, what is the minimum conductor cross-sectional area that can be used?

From Table (3-13), C_g =057 (approximated, since there being a total of 6 circuits).

From Table (3-18), C_a = 0.91
Also C_i = 1 , for HBC fuse : C_d=1,

Thus:
.

$$I_t = 28 \times \frac{1}{0.91} \times \frac{1}{0.57} A = 54.6 A$$

From Table (3-6) Column 5 the minimum conductor cross-sectional area that can be used is found to be 10 mm^2 = 69 A.

Example 2
A single-phase circuit is to be wired in 70ºC pvc-insulated and sheathed single-core cables having copper conductors. The cables are to be installed in free air, horizontal, flat spaced on cable supports (Reference Method F). If I_b = 135 A, t_a = 50ºC and overload and short circuit protection is to be provided by a BS 88 ‘gG’ fuse (BS EN60269), what is the minimum current rating for that fuse and the minimum cross-sectional area of the cable conductors that can be used?

Answer

Because $I_n \geq I_b$, select I_n = 160A from the standard ratings of BS 88 Pt 2.
Therefore I_n = 160A.
From Table 4C1, C_a = 0:71,
As there is no grouping, Cg=1

Ci =1 and Cd = 1.

Thus:

$$I_t = 160 \times \frac{1}{0.71}\ A = 225.4\ A$$

From Table (3-11) Column 2 it is found that 50 mm^2 is inadequate because I_{ta} would be only 215 A. The minimum conductor crosssectional area that can be used is 70 mm having I_{ta} = 264 A.

Example 3
Six similar single-phase circuits each having I_b = 8 A are to be wired in single-core 70ºC pvc-insulated non-sheathed cables having copper conductors. The cables are enclosed in conduit totally surrounded by thermally insulating material. If the ambient temperature is expected to be 45ºC and each circuit is protected by a 10 A miniature circuit breaker against both overload and short circuit, what is the minimum cross-sectional area of conductor that can be used?

Answer

From Table (3-18), C_a = 0:79.
From Table (3-13), C_g = 0:57.

From Table (3-4), Reference Method is A1 where the conduit enclosing the cable(s) is totally surrounded by thermally insulating material: in such cases the factor Ci (=0.5) has to be used. Thus:

$$I_t = 10 \times \frac{1}{0.79} \times \frac{1}{0.57} \times \frac{1}{0.5}\ A = 44.4\ A$$

From Column 2 of Table (3-5) it is found that the minimum conductor cross-sectional area that can be used is 10 mm^2 having I_{ta} = 46 A.

PROTECTION AGAINST FAULT CURRENT

Short-circuit current

- the short-circuit current that could flow during fault is known as the 'prospective short-circuit current' (PSCC), and any device installed to protect against such a current must be able to break it.
- Figure1 shows PSCC over one half-cycle; t_1 is the time taken to reach the total time taken from start of fault to extinguishing of the arc. ' cut-off' when the current is interrupted, and t_2 the total time taken from start of fault to extinguishing of the arc.
- During the 'pre-arcing' time t_1, electrical energy is passing through the protective device into the conductors. This is known as the 'pre-arcing let-through ' energy and is given by (I_f^2t) where I_f is the short-circuit current at 'cut-off ' The total amount of energy let-through into the conductors is given by (I_f^2t)

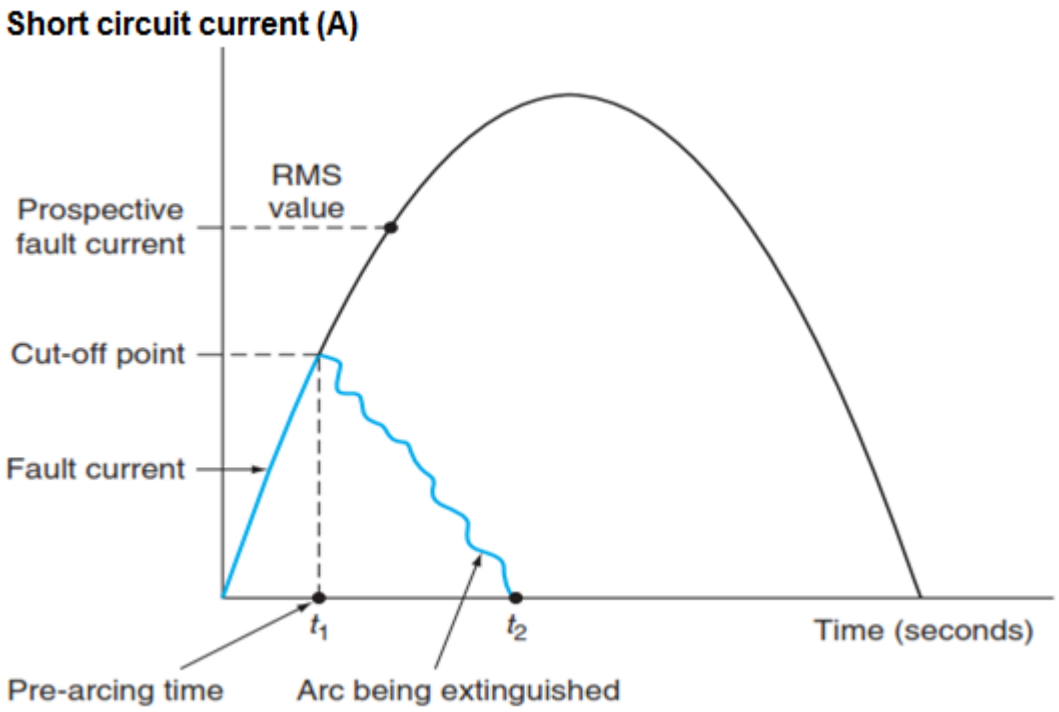


Fig.1

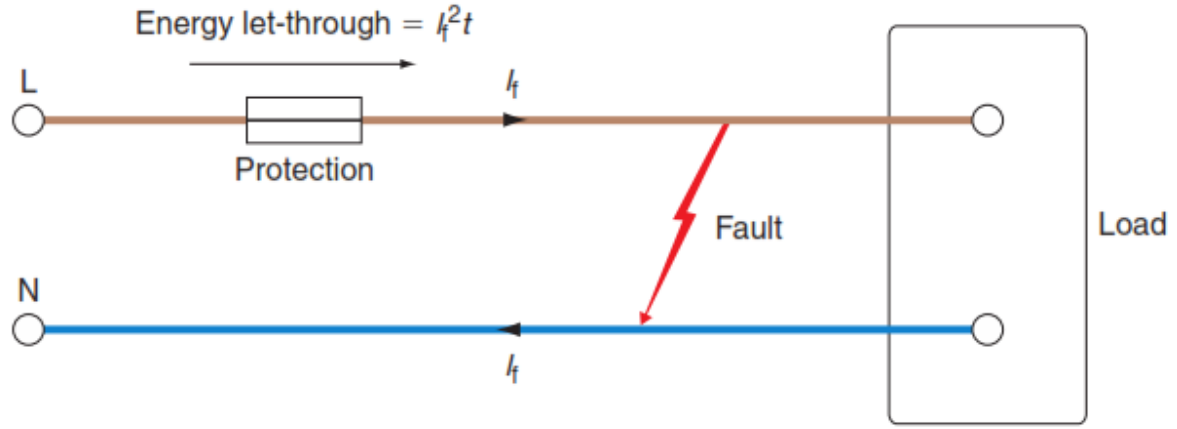


Fig.2

For faults up to 5 s duration, the amount of heat and mechanical energy that a conductor can withstand is given by $K^2 S^2$, where K is a factor dependent on the conductor and insulation materials, and S is the conductor csa.

Evaluation of thermal constraints

During short circuit , the cable is carrying the fault current during the time it takes the protective device to operate and disconnect the circuit. Because this time is very short the cable is heated adiabatically. The fault current depends on the earth fault loop impedance Zs. This impedance is the sum of the impedance of the circuit cable and the impedance of the protective conductor.
In most cases the protective device will have a breaking capacity greater than the prospective short circuit current, and this allows one to assume that the current will be disconnected sufficiently quickly to prevent overheating during a short circuit. The cable size selected from the rating tables for the working current is then adequate.
In other cases a further check must be made by means of the formula

$$s = \frac{\sqrt{I^2 t}}{k}$$

where:

s = minimum csa of the cable
I = fault current
t = disconnection time in seconds
K = Short circuit factor:

K = 115 for copper cables with PVC insulation .

K = 143 for copper cables with XLPE insulation

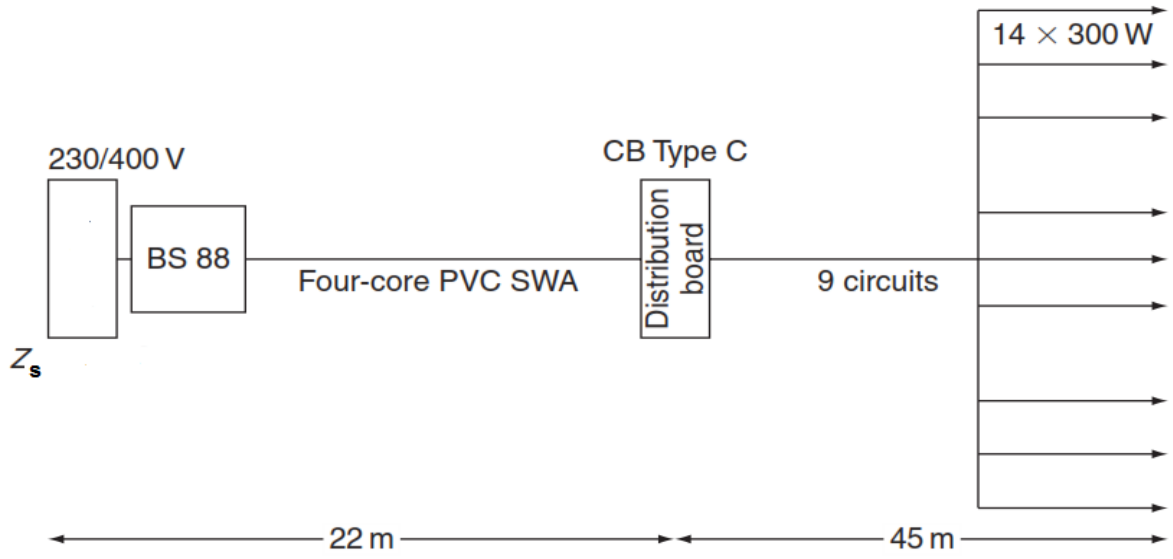
K= 76 for Aluminium cables with PVC insulation

K= 97 for Aluminium cables with PVC insulation

Example 1

Part of the lighting installation in a new warehouse (Hanger) is to comprise a distribution circuit to a three-phase lighting distribution board from which nine single-phase final circuits are to be fed. The distribution circuit, protected by BS 88 fuses, is to be four-core PVC SWA cable and is 22m long(method B1). The distribution board will house Type C CBs, and each final circuit is to supply fourteen 300 W discharge luminaires. The longest run is 45 m, and the wiring system will be singles in trunking(method B1), the first few metres of which will house all nine final circuits. The ambient temperature will not exceed 30°C.

Determine all relevant cable/conductor sizes



Solution

Design current of each final circuit I_b

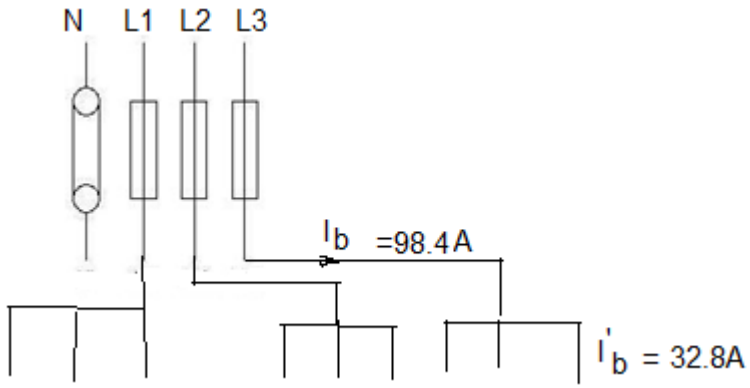
As each row comprises fourteen 300 W/230 V discharge fittings:

$$I_b' = \frac{14 \times 300 \times 1.8}{230} = 32.8\,\text{A}$$

(The 1.8 is the multiplier for discharge lamps)

As the nine circuits will be balanced over three phases, each phase will feed three rows of fittings:

I_b per phase = 3x32.8 = 98.4 A.



Distribution circuit design current I_b

Distribution circuit

I_b per phase = 98.4 A

Nominal rating of protection *In*

$$I_n \geq I_b$$

So, the protection will be 100 A

Tabulated current-carrying capacity I_t

Discharge units do cause short duration overloads at start-up, so it is perhaps best to use I_n rather than I_b:

$$I_t \geq I_n$$
$$\geq 100\,\text{A}$$

Cable selection

From Table (3-5) column 4, I_t = 101 A, giving a cable size of 25 mm ^{2}.

Voltage drop checking:

From IEC Table (3-23) column 4, the mV drop is 1.5.

$$\text{Volt drop} = \frac{1.5 \times 98.4 \times 22}{1000} = 3.23\,\text{V (acceptable)}$$

This is the three-phase drop, the single phase being:

$$\frac{3.23}{\sqrt{3}} = 1.87\,\text{V}$$

Thermal checking:

The impedance of the 25 mm^2 cable from Table (A) is 0.864 Ω/km or 2x0.864 = 1.728 Ω/km (go and return).

$$Z_c = \frac{22x1.728}{1000} = 0.038\Omega$$

$$I = \frac{V}{Z_c} = \frac{230}{0.038} = 6052.6A$$

$$s = \frac{\sqrt{I^2 t}}{k}$$

Let the protection time =0.4 s, then:

$$S = \frac{\sqrt{6052{,}6^2\ x0.4}}{115} = 33mm^2$$

Therefore a cable of 25mm^2 is not adequate, and in this case we use 35mm^2 cable.

Final circuits design current I_b

I_b' = 32.8 A (calculated previously).

Setting of protection I_n

$$I_n \geq I_b = 40\,A$$

From table (3-13) for 9 cables Cg = 0.5

Tabulated current-carrying capacity I_t

$$I_t \geq \frac{I_n}{C_g} \geq \frac{40}{0.5} \geq 80\,A$$

Cable selection

From IEE Regulations Table (3-5) column 4, $I_t \geq 80$ A = 101 A and conductor size will be 25 mm^2.

Voltage drop checking:

From Table (3-23) column 3, the mV drop for a 25 mm^2 conductor is1.51 mV.

$$\text{Volt drop} = \frac{1.51 \times 32.8 \times 45}{1000} = 3\ V$$

Add this to the sub-main single-phase drop, and the total will be:

1.87 + 3 = 4.87 (acceptable)

Thermal checking:

$$Z_c = \frac{45x1.728}{1000} = 0.077\Omega$$

$$I = \frac{V}{Z_c} = \frac{230}{0.077} = 2987A$$

t from Type C CB curve for 32 A is less than 0.1 s. ***K*** = 115 .

$$S = \frac{\sqrt{2987^2\ x0.1}}{115} = 8.2mm^2$$

Hence 25 mm^2 cable is adequate.

Table (A)

X' في درجة حرارة (Ω/كم 70 مئوية)	R' في درجة حرارة (Ω/كم 70 مئوية)	المقطع العرضي وعدد النواقل(mm^2)
0.115	14.47	4x1.5
0.110	8.71	4x2.5
0.107	5.45	4x4
0.100	3.62	4x6
0.094	2.16	4x10
0.090	1.36	4x16
0.086	0.863	4x25
0.083	0.627	4x35
0.083	0.463	4x50
0.082	0.321	4x70
0.082	0.232	4x95
0.080	0.184	4x120
0.080	0.150	4x150
0.080	0.1202	4x185
0.079	0.0922	4x240
0.079	0.0745	4x300

Calculation of the Cross-sectional Areas of Circuit Live Conductors

MOTOR CIRCUITS SUBJECT TO FREQUENT STOPPING AND STARTING

Regulations requires that where a motor is intended for intermittent duty and for frequent stopping and starting, account shall be taken of any cumulative effects of the starting periods upon the temperature rise of the equipment of the circuit. That equipment, of course, includes the cables feeding the motor.
When motors are regularly restarted soon after they have been stopped the cables supplying the motor may not have time to cool to close to the ambient temperature, this time being anything from 20 minutes or so to several hours depending on their size and method of installation.
Furthermore starting currents (for direct-on-line starting) can be between 5 and 8 times the full load current.
The calculation of any accurate factor to take account of frequent stopping and starting is complex and requires that information is provided on:

(a) the actual magnitude of the starting current
(b) the duration of, and rate of decay, of the starting current
(c) the full load current
(d) the first choice cable size to calculate its time constant
(e) the time intervals between stopping and starting.
It is suggested that the cable cross-sectional area is chosen on the basis of its current-carrying capacity being **1.4** times the full load current.

Example 1

A 10 hp 240 V single-phase motor is subject to frequent stopping and starting. The cable supplying the motor via a direct-on-line starter is two core, non-armoured cable having 85°C rubber insulation and copper conductors, clipped direct. If the ambient temperature is 50°C what should be the conductor cross-sectional area?

Answer

As 1 hp = 746 watts the full load current is:

$$\frac{10 \times 746}{240}\ \text{A} = 31.1\ \text{A}$$

The conductor current-carrying capacity should therefore be at least

1.4 x 31.1A= 43:5A.

As the ambient temperature is 50°C, from Table (3-18) (assuming the circuit overcurrent protective device is other than a BS 3036 semienclosed fuse) Ca is found to be 0.82.

The cross-sectional area of the conductor should therefore have Ia of at least 43.5/0.82 A= 53 A.

From Table (3-6) Column 6 (Method C) it is found that the minimum conductor cross-sectional area to use is 6 mm2 having I_{ta} = 58 A.

Due account has to be taken of the motor efficiency and motor power factor where these are known.

Example 2

A 415 V three-phase motor has a rating of 15 kW at a power factor of 0.8 lagging, the efficiency being 90%. If this motor is subject to frequent stopping and starting and it is intended to use a multicore armoured 70°C pvc-insulated cable having copper conductors, installed in free air, what should be their crosssectional area when ta = 35°C?

Answer

The full load current of the motor is:

$$\frac{15 \times 1000}{0.8 \times 0.9 \times \sqrt{3} \times 415}\ \text{A} = 29\ \text{A (per phase)}$$

The conductor current-carrying capacity should therefore be at least

1.4 x 29 A = 40:6A.

As the ambient temperature is 35°C, from Table (3-18) (assuming the circuit overcurrent protection device is other than a semi-enclosed fuse to BS 3036) Ca is found to be 0.94.

The cross-sectional area of the conductors should therefore have I_{ta} of at least 40.6/0.94 A=43.2 A.
From Table (3-7) Column 6 it is found that the minimum conductor cross-sectional area is 6 mm2 having I_{ta} = 41 A.

Note : in this example no mention is made of the nominal current rating of the overcurrent protective device for the motor circuit. The omission is deliberate because that device, in very many motor circuits, is providing short circuit protection only. Overload protection is provided by, for example, thermal overload relays in the motor starter. The nominal current rating of the overcurrent protective device in the motor circuit and its operating characteristics must be such as to provide adequate short circuit protection to the circuit conductors (i.e. give compliance with the adiabatic equation in Regulation 434–03–03) but not cause disconnection of the motor circuit because of high starting currents.

CIRCUITS FOR STAR-DELTA STARTING OF MOTORS

- With star-delta starters six conductors (two per phase) are required between the starter and the motor, the star or delta connections being made in the starter.
- During the running condition the current carried by each of the six cables is $1/\sqrt{3}$ times that of the supply cables to the starter (the connection being delta). If the motor cables are not grouped they require a current-carrying capacity 58% that of the supply cables.
- In practice it is far more likely that the motor cables are grouped together so that the grouping correction factor (Cg) for two circuits applies and the required current-carrying capacity for the motor cables becomes 72% that for the supply cables assuming the cables are either enclosed or bunched and clipped to a non-metallic surface.
- If a delta-connected motor is started direct-on-line the starting current may be between 5 and 8 times the full load current depending on the size and design of that motor. When star-delta starting is used the current taken from the supply is one third of that taken when starting direct on line. Hence the starting current in star may be between 1.67 and 2.67 times the full load current.

- During the starting period, because the star connection is used, the current in each of the motor cables equals that in the supply cables.Because the starting current is only carried for a short period advantage can be taken of the thermal inertia of the cables and the cables chosen on the basis of their running condition will be satisfactory for the starting current.

Example 3

A 415 V three-phase 20 kW motor has a power factor of 0.86 lagging and an efficiency of 90%. Star-delta starting is to be used. The supply cables to the starter are single-core 70°C pvc-insulated (copper conductors) in conduit. The motor cables from the starter are also single-core pvc insulated (copper conductors) and in another length of conduit. What is the minimum conductor cross-sectional area for both circuits if t_a = 30°C?

Answer

$$\text{The line current} = \frac{20 \times 1000}{\sqrt{3} \times 415 \times 0.86 \times 0.90}\ \text{A} = 35.9\ \text{A}$$

There are no correction factors to be applied.
From Table (3-5) Column 5, it is found that the minimum conductor cross-sectional area for the supply cables is 6 mm^2 having I_{ta} = 38 A.

For the cables from the starter to the motor, each cable carries

$$\frac{35.9}{\sqrt{3}}\ \text{A} = 20.7\ \text{A}$$

But now it is necessary to apply the grouping factor for two circuits which from Table (3-13) is 0.8.
Thus:

$$I_t = \frac{20.7}{0.8}\ \text{A} = 25.9\ \text{A}$$

Again from Table (3-5) Column 5 it is found that these cables can be of $4mm^2$ = 30 A.

As already stated, whilst during starting the cables between the motor cross-sectional area, having Ita and starter may be carrying a current of 35.9 x2.67 A (= 96 A), but the time the motor is held in star will generally be less than the time taken for these cables to reach the maximum permitted normal operating temperature.

Summary

Cable current carrying capacity calculations

1. Assessment of general characteristics
2. Determination of design current *I* b
3. Selection of protective device having nominal rating or setting *In*
4. Selection of appropriate rating factors
5. Calculation of tabulated conductor current *It*
6. Selection of suitable conductor size
7. Calculation of voltage drop
8. Evaluation of thermal risks to conductors.

Design current *I* b

This is defined as '*the magnitude of the current to be carried by a circuit in normal service* ' ,and is either determined directly from manufacturers' details or calculated using the following formulae:

Single phase:

$$I_b = \frac{P}{V} \quad \text{or} \quad \frac{P}{V \times \text{Eff}\% \times \text{PF}}$$

For three-phase :

$$I_b = \frac{P}{\sqrt{3} \times V_L} \quad \text{or} \quad \frac{P}{\sqrt{3} \times V_L \times \text{Eff\%} \times \text{PF}}$$

where:

P = power in watts
V = line to neutral voltage in volts
V_L = line to line voltage in volts
Eff% = efficiency
PF = power factor.

C_a	Factor for ambient air and ground temperature	(From IEC Regulations Tables (3-18)
C_g	Factor for groups of cables	(From IEE Regulations Table (3-13) to (3-17) and (3-19) to (3-22) for U/G cables
C_c	Factor:	
	if Semi-enc (re-wireable) fuse is used	(Factor is 0.725)
	if cable is buried direct in the ground	(Factor is 0.9)
	if both are involved	(Factor is 0.9 × 0.725 = 0.653)
C_i	Factor if cable is surrounded by thermally insulating material	(Ci Factor is 0.5)

Tabulated conductor current-carrying capacity I_t

$$I_t \geq \frac{I_n}{C_a \times C_g \times C_c \times C_i}$$

Note 1: Remember, only the relevant factors are to be used!

Note 2: In overload protection, the IEC and IEE Regulations permit the omission of such protection in certain circumstances; in these circumstances, I_n is replaced by I_b and the formula becomes:

$$I_n \geq \frac{I_b}{C_a \times C_g \times C_c \times C_i}$$

Voltage drop

Volt drop = mV/A/m

Table 1 Voltage drop values.

	Lighting	Power
	3%	5%
230 V single phase	6.9 V	11.5V
400 V three phase	12 V	20V

or fully translated with I_b for A and L (length in metres):

$$\text{Volt drop} = \frac{\text{mV} \times I_b \times \text{length}}{1000} \text{ volts}$$

For conductor sizes voltage drops Table (3-23) may be used .

Evaluation of thermal constraints

$$s = \frac{\sqrt{I^2 t}}{k}$$

where:

s = minimum csa of the conductor
I = fault current
t = disconnection time in seconds
k = Short – circuit factor

Electrical Load Estimation

Important definitions for load estimation:

- Load estimation requires analysis of load characteristics and will take into account the demand factor relationship between connected loads and the actual demand imposed on the system.

- *a. Preliminary loads.* The load data given in the first design stage and will be used to compute preliminary estimates of the expected maximum demands and electrical energy usage. These values allow computations to be made for either population or building area.

- *b. Demand factor.* Demand factors will be applied to connected loads when calculating the required ampere capacity (ampacity) of conductors, capacity of transformers, and all equipment associated with distribution of electrical power to utilization equipment.

- *c. Diversity and diversity factor.* Is the application of diversity to installation permits, by assuming that not all loads will be energized at the same time, for example, not all lighting points at a house are operating at the same time. Also not all the socket outlet point works at the same time. Hence Diversity Factors (DF) will be applied to the demand loads when calculating the required ampacity of service and feeder conductors, distribution transformers, and all other distribution system equipment. Typical diversity factors are given in table 7- 1and table 7-2 (from Jordanian code). It is for the designer to make a careful judgment as to the exact level of diversity to be applied.

- *d. Load factor*

Table 7-1 current requirements for different power points and equipmen

الجدول (٧ – ١)

طلب التيار المفترض لنقط الإفادة والمعدات المستخدمة للتيار.

نقط الإفادة والمعدات المستخدمة للتيار	طلب التيار المفترض
مقابس عدا عن المقابس ذات التيار المقرر (2) أمبير وعدا عن المقابس ذات التيار المقرر (13) أمبير. انظر الملاحظة (١).	- التيار المقرر.
مقابس ذات تيار مقرر (13) أمبير. انظر الملاحظة (٢).	تيار يكافئ الحمل المربوط بحد أدنى (250) فولط لكل مقبس، على ألا يزيد عدد المقابس عن عدد المقابس الموزعة حسب الترتيب القياسي للدارات الكهربائية كما هو وارد في المادة (٤/٧).
ساعة كهربائية ، وحدة تغذية لماكينة حلاقة (تطابق المواصفة القياسية البريطانية (BS 3535))، مقبس لماكينة حلاقة (يطابق المواصفات القياسية البريطانية (BS 4573)، محول جرس كهربائي، ومعدات مستخدمة للتيار ذات مقرر لا يزيد عن (5) فولط أمبير.	يمكن إهمالها.
أجهزة طبخ منزلية.	أول (10) أمبير من التيار المقرر + 30 % من باقي التيار المقرر + (5) أمبير إذا كان في وحدة التحكم مقبس.
جميع المعدات الثابتة.	التيار المقرر حسب المواصفات القياسية البريطانية، أو التيار العادي.

ملاحظة:

(١) انظر المادة (٤/٧) فيما يتعلق بتصميم الدارات القياسية باستعمال مقابس مطابقة للمواصفات القياسية البريطانية (BS 1363-2) و (BS 4343).

(٢) يجب أن تكون الدارات النهائية للإضاءة التفريغية مرتبة بحيث تكون قادرة على حمل التيار الكلي المستقر أي حمل المصباح/المصابيح وأي طقم مرافق وكذلك تياراتها التوافقية. وحيث لا تتوفر معلومات ذات دقة أكثر فإن الطلب بالفولط أمبير يؤخذ على أنه القدرة المقررة للمصباح بالواط مضروبة في عامل لا يقل عن (1.8). وعامل الضرب هذا مبني على افتراض أن الدارة معدلة لعامل قدرة متأخر (Lagging) لا يقل عن (0.85) وتأخذ الدقة في طقم التحكم والتيار التوافقي في الحسبان.

Table (7-2) Diversity factor (عامل التباين اوالتشتت) according Jordan regulations

الجدول (٧ – ٢)

السماحات للتشتت (التطابق).

الغرض من الدارة النهائية المغذاة من موصلات أو طقم مبدلات ينطبق عليها التشتت	نوع المرفق		
	تمديدات منزلية منفردة شاملة مساكن منفردة من مجموعات سكنية.	متاجر صغيرة، مخازن، مكاتب ومرافق تجارية.	فنادق صغيرة، بيوت سكنية، بيوت ضيافة، ... الخ
١. إنارة	66 بالمائة من طلب التيار الكلي	90 بالمائة من طلب التيار الكلي	75 بالمائة من طلب التيار الكلي.
٢. تدفئة وقدرة (انظر البندين (٣) و (٨) أدناه)	100 بالمائة من طلب التيار الكلي حتى (10) أمبير + 50 بالمائة من أي طلب تيار زيادة عن (10) أمبير	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 75 بالمائة من تيار الحمل الكلي للأجهزة المتبقية	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 80 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر + 60 بالمائة من الحمل الكلي للأجهزة الباقية.
٣. أجهزة الطبخ	(10) أمبير + 30 بالمائة من تيار الحمل الكامل لأجهزة الطبخ المربوطة زيادة عن (10) أمبير + (5) أمبير إذا كانت وحدة التحكم تحتوي على مقبس.	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 80 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر + 60 بالمائة من تيار الحمل الكامل لكل من الأجهزة الباقية.	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 80 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر+ 60 بالمائة من تيار الحمل الكامل للأجهزة الباقية.

تابع للجدول (٧ – ٢)

السماحات للتشتت (التطابق).

الغرض من الدارة النهائية المغذاة من موصلات أو طقم مبدلات ينطبق عليها التشتت	نوع المرفق		
	تمديدات منزلية منفردة شاملة مساكن منفردة من مجموعات سكنية	مبانٍ تجارية صغيرة، مخازن، مكاتب ومرافق تجارية (رجال أعمال)	فنادق صغيرة، بيوت سكنية، بيوت ضيافة، ... الخ
٤. محركات (عدا عن محركات المصاعد التي تخضع لاعتبارات خاصة)	غير قابلة للتطبيق	100 بالمائة من تيار الحمل الكامل لأكبر محرك + 80 بالمائة من تيار الحمل الكامل للمحرك الذي يليه في الكبر + 60 بالمائة من تيار الحمل الكامل للمحركات المتبقية.	100 بالمائة من تيار الحمل الكامل لأكبر محرك + 50 بالمائة من تيار الحمل الكامل لباقي المحركات.
٥. سخانات الماء (النوع اللحظي*)	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 100 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر + 25 بالمائة من تيار الحمل الكامل للأجهزة المتبقية.	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 100 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر + 25 بالمائة من تيار الحمل الكامل للأجهزة المتبقية.	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 100 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر + 25 بالمائة من تيار الحمل الكامل للأجهزة المتبقية.
٦. سخانات الماء (ذات التحكم عن طريق ثيرموستات)	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +	لا يسمح بأي تشتت، إذ يستعمل الحمل الكامل. +

تابع للجدول (٧ – ٢)

السماحات للتشتت (التطابق).

الغرض من الدارة النهائية المغذاة من موصلات أو طقم مبدلات ينطبق عليها التشتت	نوع المرفق		
	تمديدات منزلية منفردة شاملة مساكن منفردة من مجموعات سكنية.	متاجر صغيرة، مخازن، مكاتب ومرافق تجارية، (رجال أعمال)	فنادق صغيرة، بيوت سكنية، بيوت ضيافة، ... الخ
٧. تمديدات تدفئة للأرضية	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل +	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +
٨. تمديدات تدفئة عن طريق تخزين حراري فضائي	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل +	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +
٩. ترتيبات قياسية للدارات النهائية طبقا للمادة (٤/٧).	100 بالمائة من طلب التيار لأكبر دارة + 40 بالمائة من طلب التيار لكل دارة أخرى	100 بالمائة من طلب التيار لأكبر دارة + 50 بالمائة من طلب التيار لكل دارة أخرى.	
١٠. مقابس عدا عن تلك الواردة في (٩) أعلاه والمعدات الثابتة عدا عن تلك المجدولة أعلاه	100 بالمائة من طلب التيار لأكبر نقطة إفادة +40 بالمائة من طلب التيار لكل نقطة إفادة أخرى.	100 بالمائة من طلب التيار لأكبر نقطة إفادة +70 بالمائة من طلب التيار لكل نقطة إفادة أخرى.	100 بالمائة من طلب التيار لأكبر نقطة إفادة + 75 بالمائة من طلب التيار لكل نقطة إفادة في الغرف الرئيسية (غرفة السفرة ... الخ) + 40 بالمائة من طلب التيار لكل نقطة إفادة أخرى.

* لغرض هذا الجدول، يحكم على سخان الماء بأنه سخان ماء بأي حمل إذا كان يسخن الماء فقط عندما يكون الصنبور مفتوحا ولذلك يستعمل الكهرباء بشكل متقطع.

\+ من المهم التأكد من أن لوحات التوزيع ووحدات المستهلك ذات مقرر كاف لاستيعاب الحمل الكلي الموصول معها دون تطبيق التشتت.

Demand factors for large building

Lighting	80-90%
13A socket outlets	50 %
Air-conditioning (HVAC)	85%
Lifts and elevators	50%
Lab equipment	25%
X-ray equipment	10%

Example: Table.1 shows the electrical load schedule for a bakery shop. Estimate the total electrical load of the shop.

Table 1 Electric load schedule for bakery shop

Lighting Discharg lamps	total=4kW
Lighting ordinary Lamps	24 points
13 A socket outlets	3x30A
Water heater with thermostat	4x2.5 kW
Instant water heater	3x 10 kW
Electric cookers and kitchen appliance	3x 4 kW

Supply voltage : three-phase 400/230 V.

Solution :

- Design current I_b for Discharge lighting load ;

  From table (7-2) (1) column 3 and Note 2 on table (7-1)

$$\mathrm{I} = \frac{1.8\mathrm{x}4\mathrm{x}1000\mathrm{x}90\%}{230} = 9.39\ \mathrm{A}$$

- I_b for ordinary lighting : From table (7-2) – (1) Column 3

$$I = \frac{Watts\ x\ 90\%}{V\ cos\varphi} = \frac{100x24\ x90\%}{230x1} = 9.39A$$

- 13A ring circuit socket outlets: From Table (7-2) sec.9 column 3

$$I = 30x100\% + 30\ x\ 50\% + 30x50\% = 60A$$

- Water heater: From Table (7-2) sec.6, column 3 we take the total load with pf=1.

$$I = \frac{4x2.5x1000}{230x1} = 43.48\ A$$

- Instant water heater : From Table (7-2) ,column 3 , pf=1:

$$I = \frac{10x1000x100\%}{230x1} + \frac{10x1000x100\%}{230x1} + \frac{10x1000x25\%}{230x1} = 97.83\ A$$

- Kitchen equipment: From table (7-2), sec.6, column 3 we take total load and pf=1. For one cooker:

$$I = \frac{4x1000}{230x1} = 17.39\ A$$

Taking diversity factors into consideration:

$$I = 17.39x100\% + 17.39x80\%\ 17.39x60\% = 41.74\ A$$

Hence the total current demands:

$$I = 41.74 + 97.83 + 43.48 + 60 + 9.39 = 280.61\ \text{A}$$

The design current per phase I_b :

$$I_b = \frac{280.61}{3} = 93.54\ A$$

Protection device I_n ($I_n \geq I_b$) , hence I_n = 100A for one phase.

Illumination (Lamps &Lighting)

- Illumination or lighting is the deliberate use of light to achieve a practical or aesthetic effect. In our context Lighting includes the use of artificial light sources like lamps and light fixtures in buildings.

- Proper lighting can enhance task performance, improve the appearance of an area, or have positive psychological effects on occupants..

- Light sources should be as small as possible, produce light efficiently and have a long life.

Type of Lamps

1- **Incandescent lamp**

2- **high-intensity discharge lamp (HID)**

- **Mercury-vapour lamp, Metal-halide** (HMI, HQI, CDM),

- **Sodium vapour** or "high-pressure sodium"

3-Fluorescent

Fluorescent lamp, compact fluorescent lamp (CFL),

6. Light-emitting diode (LED) light (solid-state lighting),

7- Fibber Optic light.

1- Incandescent lamp

Incandescent light bulbs consist of an air-tight glass enclosure (the envelope, or bulb) with a filament of tungsten wire inside the bulb, The bulb is filled with an inert gas such as argon (93%) and nitrogen (7%) to reduce evaporation of the filament and prevent its oxidation. The lamp is shown in Fig.1 . This lamp is called the general lighting service lamp (GLS).

1. Outline of Glass bulb
2. Low pressure inert gas
3. Tungsten filament
4. Contact wire (goes out of stem)
5. Contact wire (goes into stem)
6. Support wires
7. Stem (glass mount)
8. Contact wire (goes out of stem)
9. Cap (sleeve)
10. Insulation (vitrite)
11. Electrical contact

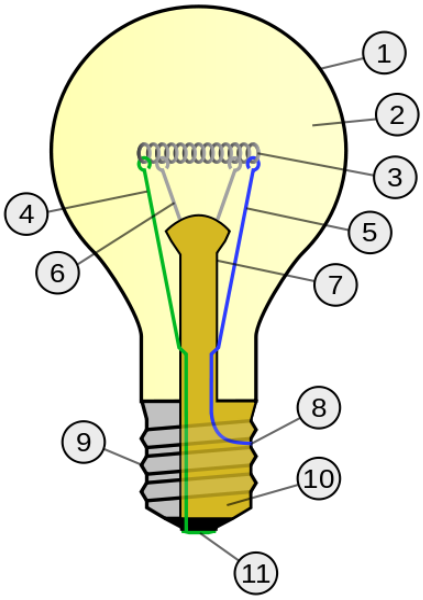


Fig.1 General lighting service incandescent lamp.

The **lumen & Lux**

- The **lumen** (symbol: **lm**) is the unit of luminous flux, a measure of the total "amount" of visible light emitted by a source.

- A **lux** is one lumen per square meter. Table -1 gives the output luminous flux in lumen for incandescent lamps.

Table-1	240 volt incandescent lamps	
Power (W)	**Output (lm)**	**Efficacy (lm/W)**
5	25	5
15	100	6.3
25	200	8.0
40	500	12.5
60	850	14.2
75	1,200	16.0
100	1,700	17.0
150	2,850	19.0
200	3,900	19.5
300	6,200	20.7

Standard Lamp Caps

Table-2

Lamps Caps		قاعدة المصباح
Description (التفاصيل)	التسمية	Symbol الرمز
Small bayonet cap قاعدة بايونت مسمارية صغيرة	**SBC**	**B15d**
Bayonet cap قاعدة بايونيت مسمارية اعتيادية	**BC**	**B22d**
قاعدة من البايونيت بثلاث مسامير	**3pin-BC**	**B22d-3**
قاعدة لولب اديسون صغير **Small Edison screw**	**SES**	**E14**
لولب اديسون اعتيادي **Edison screw**	**ES**	**E27**
لولب أديسون كبير(غولياث) **Goliath Edison screw**	**GES**	**E40**

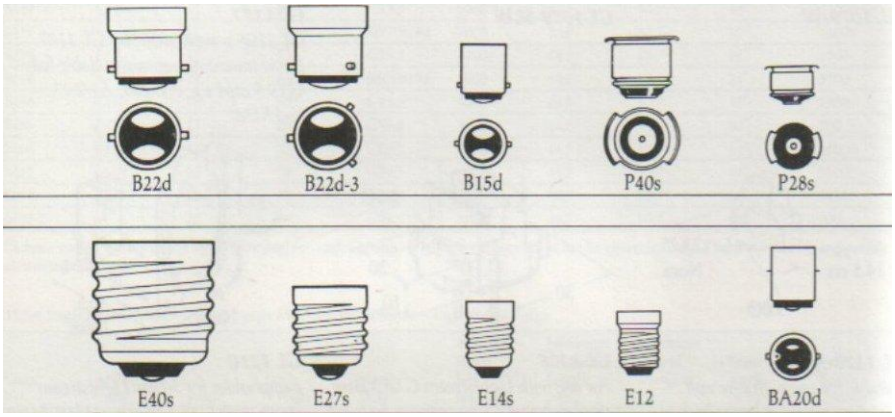


Fig.2 Incandescent lamps standard caps and various shapes of lamps

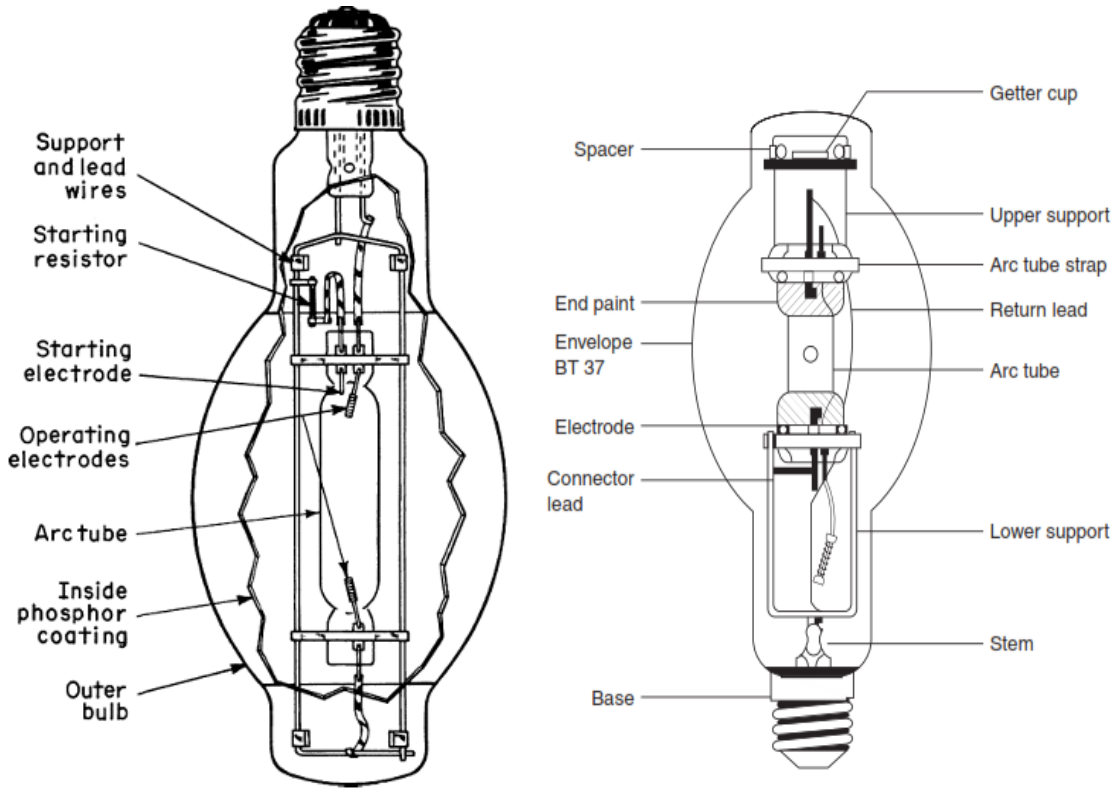
2-Halogen lamps

The lamp is filled with a halogen gas at low pressure, instead of an inert gas. Such bulbs are much smaller than normal incandescent bulbs, and are widely used where intense illumination is needed in a limited space. Useful life is three time the incandescent la

3- Gas-discharge lamp

❖ ***High-Intensity Discharge (HID).*** This term denotes a general group of lamps consisting of :

- Mercury-vapor lamps
- Metal halide lamps
- High – pressure sodium vapor lamps
- Xenon arc lamps



(a) (b)

FIGURE 3 (a) A 400-W phosphor-coated mercury lamp, (b) A metal-Halide lamp.

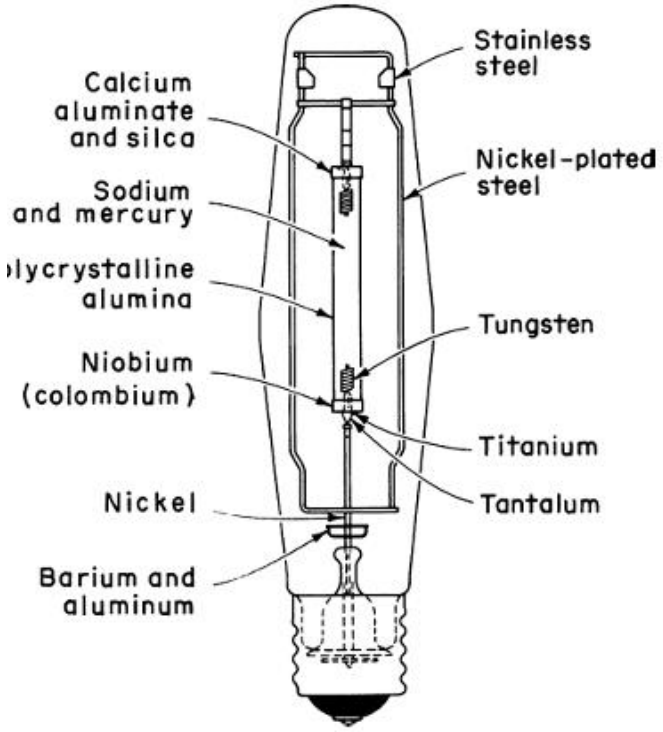


Fig.4 High – pressure sodium light.

❖ **Low-pressure discharge lamps**

- ***FLUORESCENT LAMPS***

Fluorescent lamps are low-pressure mercury electric-discharge lamps in which a phosphor coating transforms of the ultraviolet energy generated by the discharge arc into light. Fluorescent lamps are the most common lamp in office lighting and many other applications, produces up to 100 lumens per watt

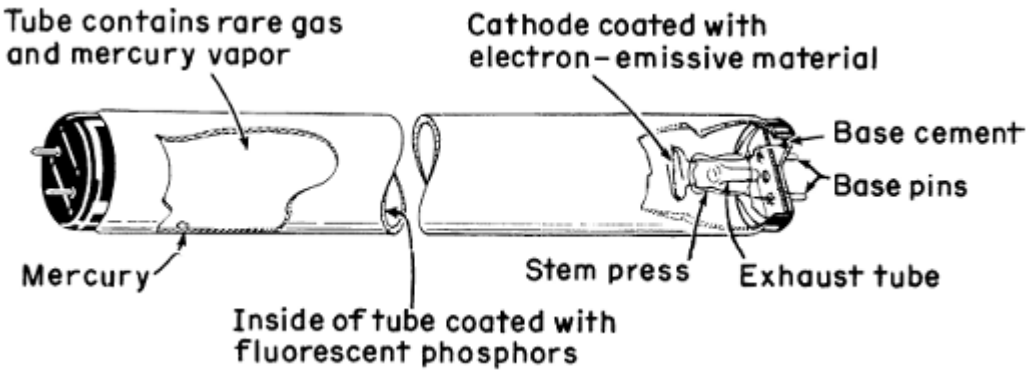


Fig.5 Cutaway view of fluorescent lamp.

- ***Compact Fluorescent Lamps.*** Energy-conservation activities have focused attention on the relatively low efficacy and short life of general-service 25- to 100-W incandescent lamps widely used in many residential, commercial, institutional, and industrial applications. Compact fluorescent lamps provide significantly higher efficacy and come in a variety of sizes and wattages

Fig.6 Compact fluorescent lamps.

- Low pressure sodium lamps, the most efficient gas-discharge lamp type, producing up to 200 lumens per watt, it produce yellow light which is the only acceptable colour for street lighting and similar applications.

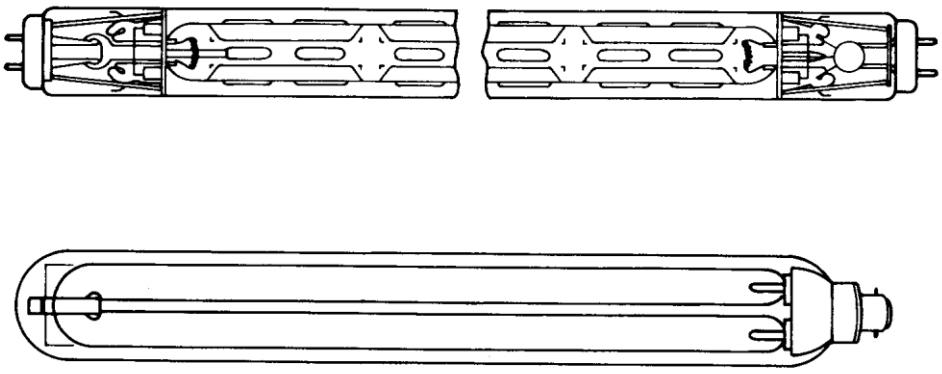


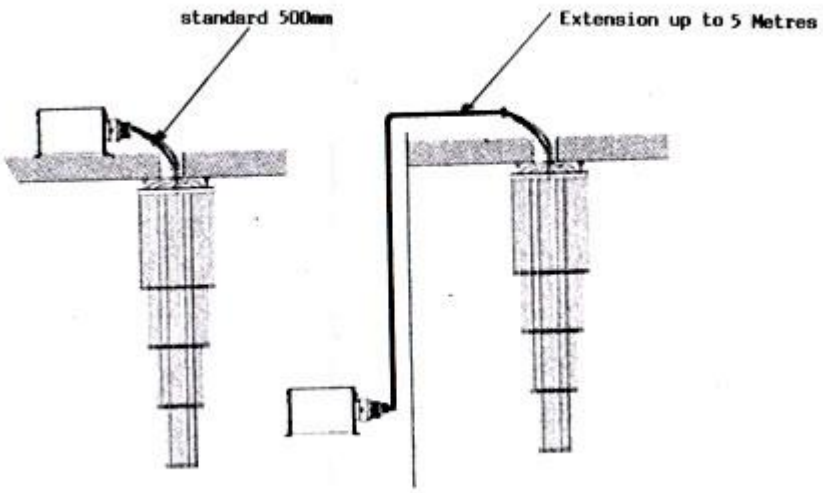
Fig.7 Low pressure sodium lamp.

4. **light-emitting diode** (**LED**)

This is a two-lead semiconductor light source that resembles a basic pn-junction diode, except that an LED also emits light.
Light sources should be as small as possible, produce light efficiently and have a long life. Only light emitting diodes (LEDs), also called light diodes, achieve this. They conform to the lighting designer's ideal of a pointlike light source: no other lamp possesses comparably small dimensions.

Fig.8 LED lamps

5. LASER Light



Light Source

Projector, with i high output 250W

Metal Halide lamp,

with ability to have two colour/effect

wheels fitted when required.

Fibre optic light

Lighting Technology

Basic parameters used in lighting

Luminous flux – Luminous intensity – Illuminance – Luminance

- **Luminous flux**

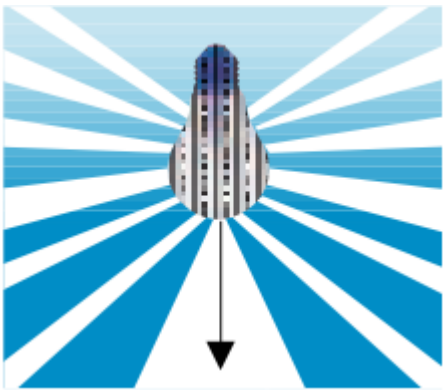
Luminous flux **(ϕ)** is the light emitted by a source and is measured in **lumens**

Symbol	ϕ
Unit :	Lumen

- **Luminous intensity**

Luminous intensity is the power of light from the source measured in **candela**

Symbol	I
Unit :	Candela (cd)



- **Illuminance**

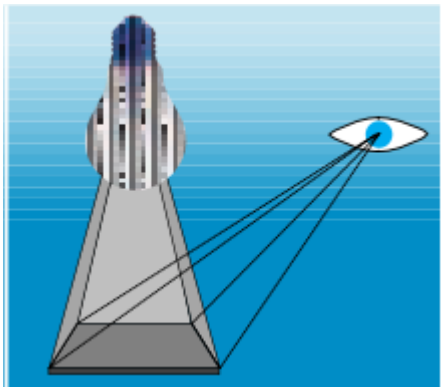
  Illuminance is a measure of the density of luminous flux at a surface measured in **lux** (lumens per square metre)

$$E\ (lx) = \frac{luminous\ flux\ (lm)}{area\ (m^2)}$$

- **Luminance**

Luminance is a measure of the light reflected from a surface measured in **candela per m^2**

Symbol	L
Unit :	cd/m^2

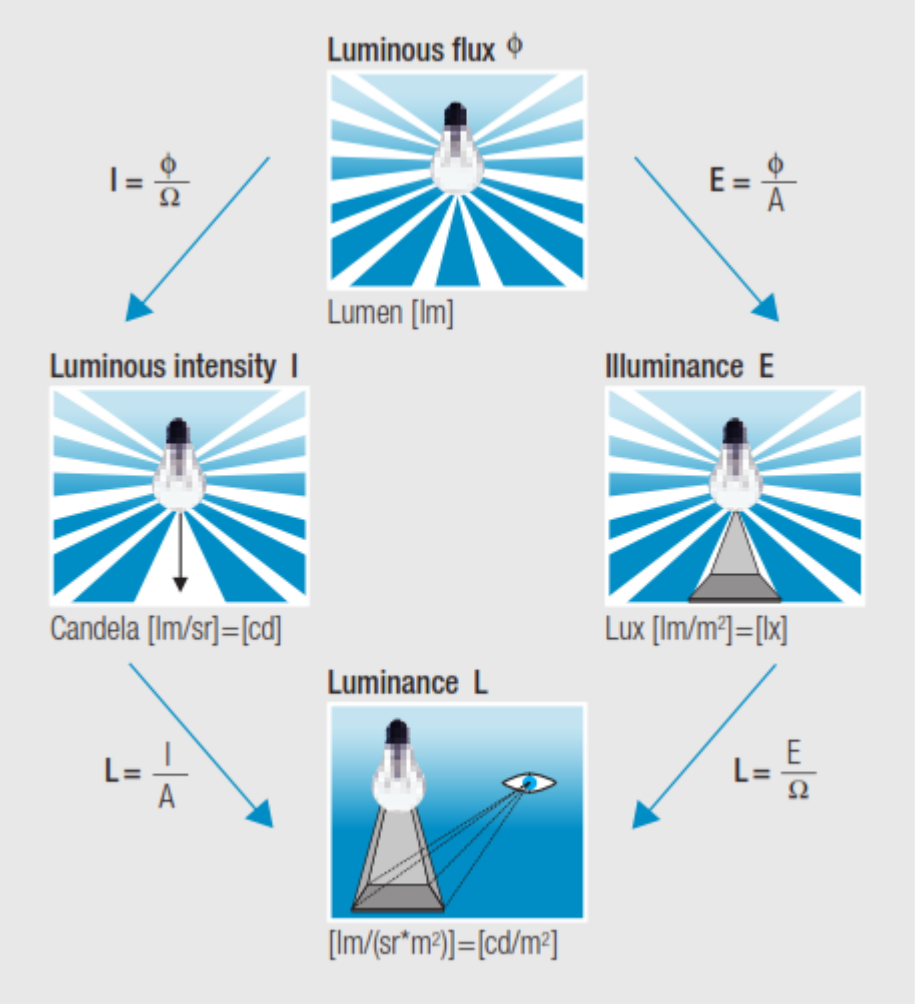


The luminous **efficiency:**

- is the ratio of the luminous flux to the electrical power consumed (lm/W). It is a measure of a lamp's economic efficiency.

0r

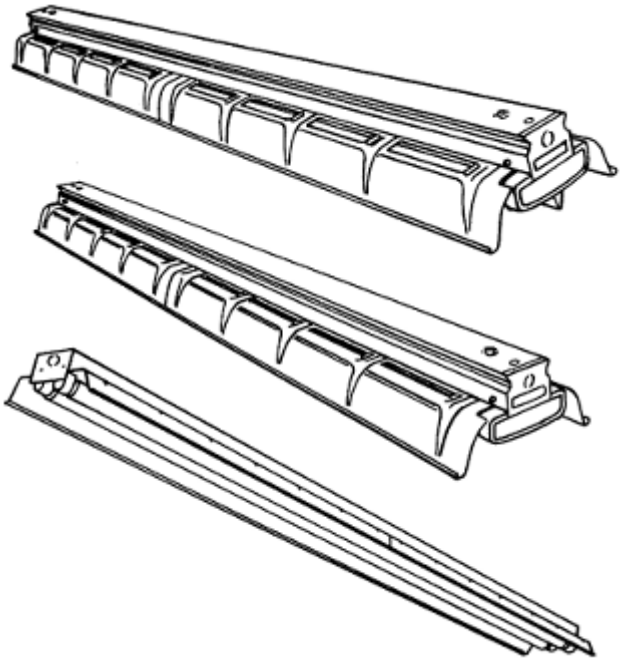
- Luminous **efficacy** is the ratio of the luminous flux emitted by a lamp to the power the lamp consumes this is measured in **lumens per watt.**



Luminaire

A **light fixture** (US English), **light fitting** (UK English), or **luminaire** is a complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

All luminaires have a fixture body and a light socket to hold the lamp and allow for its replacement. Also they may a have a switch to control the light. Typical luminairs are shown in Fig.1.



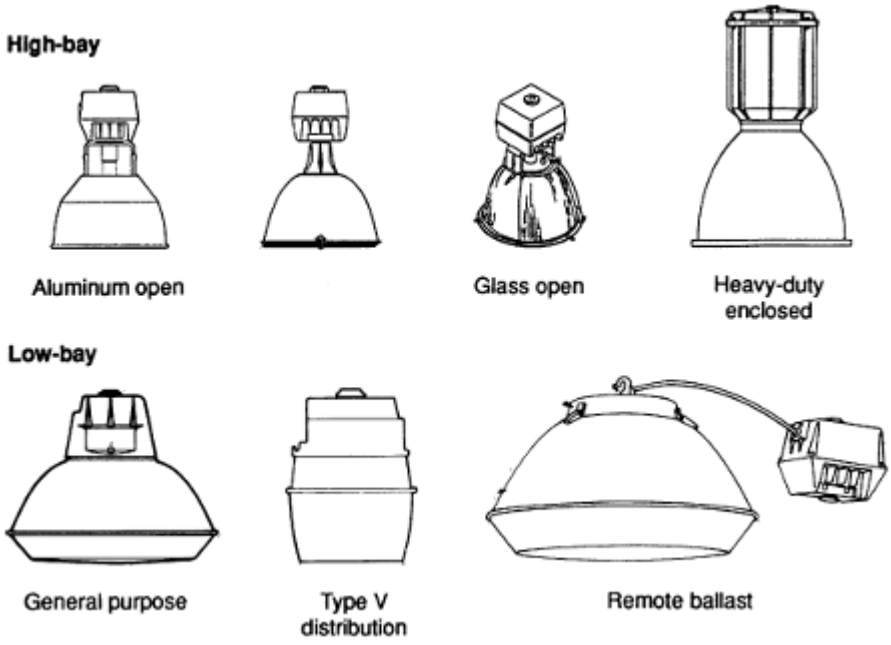

High-bay
Aluminum open
Glass open
Heavy-duty enclosed
Low-bay
General purpose
Type V distribution
Remote ballast

Fig.1

Lighting calculations

UNITS AND QUANTITIES

Quantity	*Quantity symbol*	*Unit*	*Unit Symbol*
Luminous intensity	I	Candela	cd
Luminous flux	Φ	Lumens	lm
Illuminance	E	Lux	lx
Luminance	L	Candela square metre	cd/m^2
Luminous efficacy		Lumens per watt	lm/W

Methods of Lighting Calculation

In general , there are three methods of lighting calculations :

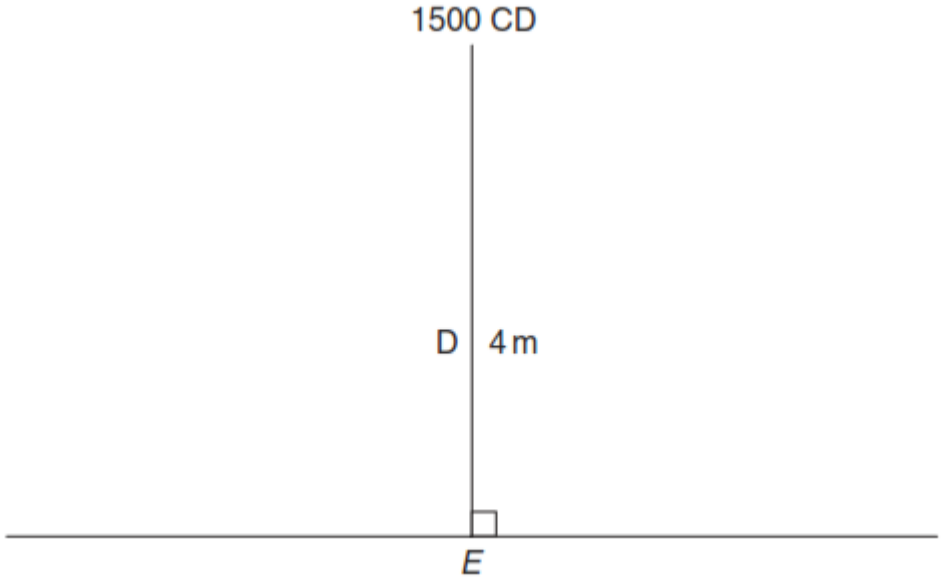
- Inverse square law
- Cosine law
- Lumen method (most common)

Inverse square law

When using the inverse square law, the distance used in the measurement is from the light source to a point directly below it. When a lamp is suspended above a surface, the illuminance at a point below the lamp can be calculated:

$$\text{Illuminance } E = \frac{(I)\ \text{candela}}{\text{distance}^2}\ \text{lux}$$
$$= \frac{I}{\text{d}^2}$$

EXAMPLE 1 A luminaire producing a luminous intensity of 1500 candela in all directions below the horizontal, is suspended 4m above a surface. Calculate the illuminance produced on the surface immediately below the luminaire.



$$E = \frac{I}{\text{d}^2}$$
$$= \frac{1500}{4^2}$$
$$= 93.75\ \text{lux}$$

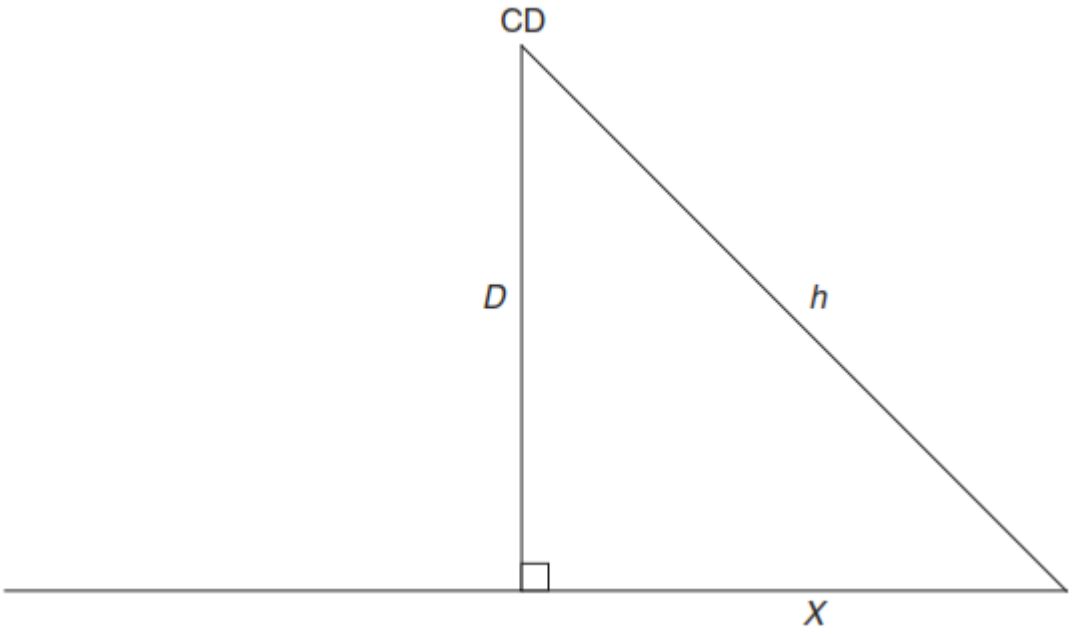
EXAMPLE 2 If the luminaire in Example 1 is raised by 1m, what would the new illuminance be at the point immediately below the surface?

$$E = \frac{1500}{(4+1)^2}$$
$$= \frac{1500}{5^2}$$
$$= 60 \text{ lux}$$

COSINE LAW

When using the cosine law, the distance used is from the light source measured at an angle to the point at which the lux value is required. When a lamp is suspended above a horizontal surface, the illuminance (*E*) at any point below the surface can be calculated.

$$E = \frac{I}{h^2} \cos\phi$$



To calculate h^2 (distance from lamp)

$$h^2 = d^2 + x^2$$

To calculate $\cos\phi$

$$\cos\phi = \frac{d}{h}$$

EXAMPLE 1 A light source producing 1500 candela is suspended 2.2 m above a horizontal surface. Calculate the illumination produced on the surface 2.5 m away (at *Q*).

Solution

Calculate h^2 using Pythagoras.

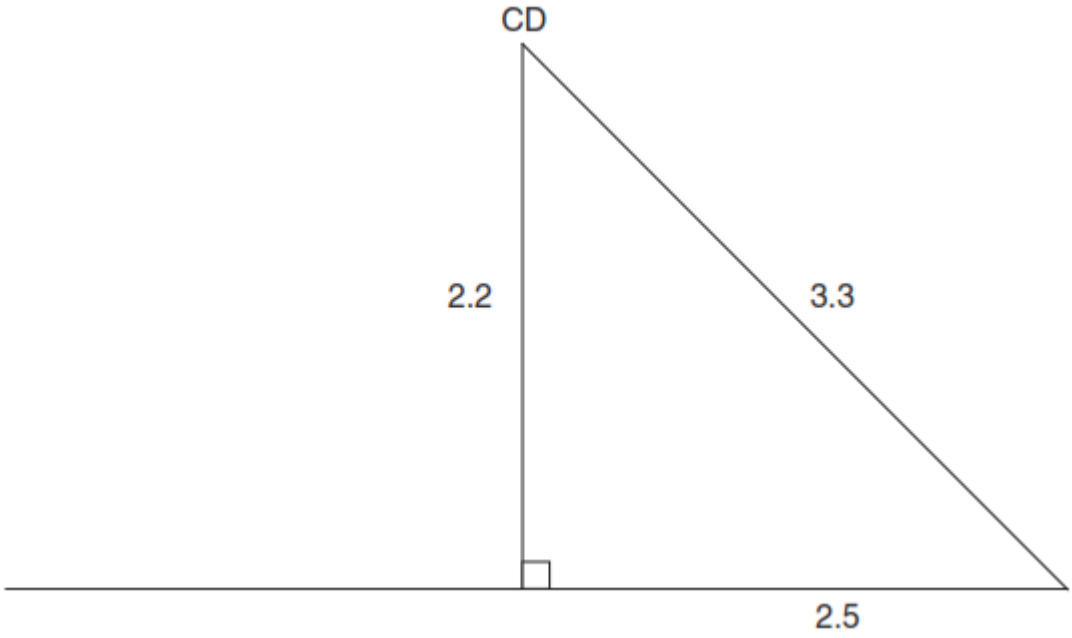
$$h^2 = d^2 + x^2$$
$$= 2.2^2 + 2.5^2$$
$$h^2 = 11.09$$

Calculate h

$$= \sqrt{h^2}$$
$$= 3.33$$

Calculate $\cos\phi$ using pythagoras

$$= \frac{d}{h}$$
$$= \frac{2.2}{3.33}$$
$$= 0.66$$
$$E_Q = \frac{1500}{11.09} \times 0.66$$
$$= 89.26 \text{ lux}$$



EXAMPLE 2 Two lamps are suspended 10m apart and at a height of 3.5 m above a surface (Figure 2). Each lamp emits 350cd. Calculate.
(a) the illuminance on the surface midway between the lamps,
(b) the illuminance on the surface immediately below each of the lamps.

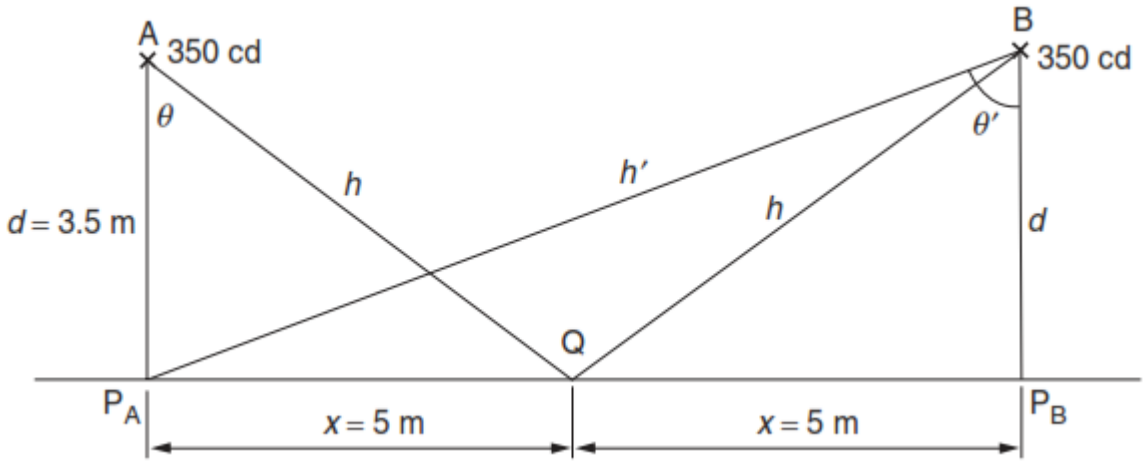


Fig.2

Solution :

(a) For one lamp, the illuminance at Q is

$$E_{\mathrm{Q}} = \frac{I}{h^2}\cos\theta$$

$$= \frac{350}{3.5^2 + 5^2} \times \frac{3.5}{\sqrt{(3.5^2 + 5^2)}}$$

$$= \frac{350}{12.25 + 25} \times \frac{3.5}{\sqrt{(12.25 + 25)}}$$

$$= \frac{350}{37.25} \times \frac{350}{\sqrt{37.25}}$$

$$= 5.388\,\mathrm{lx}$$

The illuminance from two lamps is double that due to one lamp, since the conditions for both lamps are identical. Thus total illuminance at Q = 2 × 5.388 = 11.8 lx

(b) At P_A below lamp A, the illuminance due to lamp A is

$$E_{\mathrm{P_A}} = \frac{I}{d^2}$$

$$= \frac{350}{3.5^2}$$

$$= 28.57\,\mathrm{lx}$$

In calculating the illuminance at PA due to lamp B, we have a new distance *h'* , a new distance *x'* , and a new angle *θ'* to consider.

$$x' = 2x$$

$$= 10$$

$$(h')^2 = 3.5^2 + 10^2$$

$$= 112.25$$

$$\therefore \quad (h') = 10.59$$

$$\cos\theta' = \frac{d}{h'} = \frac{3.5}{10.59} = 0.331$$

$\therefore$ illuminance at P_A due to lamp B is

$$E_{P_B} = \frac{350}{112.25} \times 0.331 = 1.013$$

$$\text{Total illuminance at } P_A = 28.57 + 1.013 = 29.61 \text{ lx}$$

and, as the conditions at PB are the same as those at PA , this will also be the illuminance below lamp B.

Problems

1. A lamp emitting 450 cd in all directions is suspended 3m above the floor. The illuminance on the floor immediately below the lamp is

(a) 150 lx **(b)** 1350 lx **(c)** 50 lx **(d)** 0.02 lx

2. If the lamp of question 7 is reduced in height by 0.5 m, the illuminance produced immediately below it is

(a) 72 lx **(b)** 36.7 lx **(c)** 129 lx **(d)** 180 lx

Lighting Technology

Basic parameters used in lighting

Luminous flux – Luminous intensity – Illuminance – Luminance

- **Luminous flux**

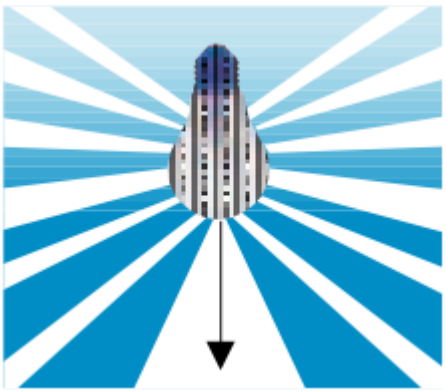
Luminous flux **(ϕ)** is the light emitted by a source and is measured in **lumens**

Symbol	ϕ
Unit :	Lumen

- **Luminous intensity**

Luminous intensity is the power of light from the source measured in **candela**

Symbol	I
Unit :	Candela (cd)



- **Illuminance**

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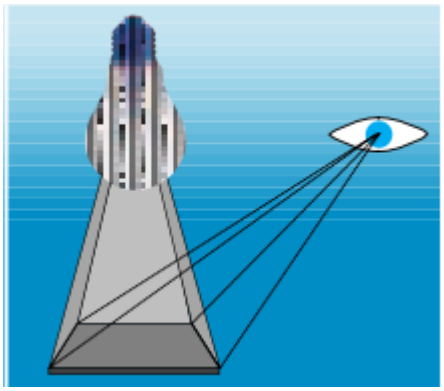
$$E\ (lx) = \frac{luminous\ flux\ (lm)}{area\ (m^2)}$$

- **Luminance**

Luminance is a measure of the light reflected from a surface measured in **candela per m^2**

Symbol	L
Unit :	cd/m^2



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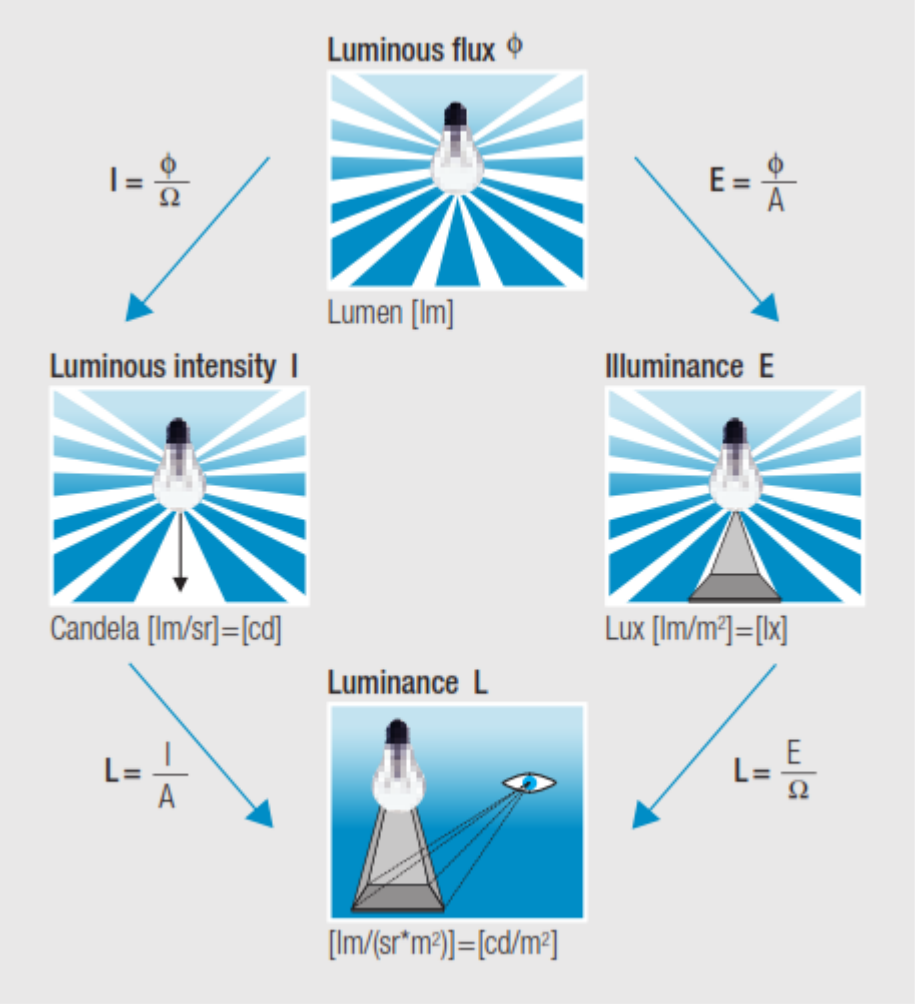

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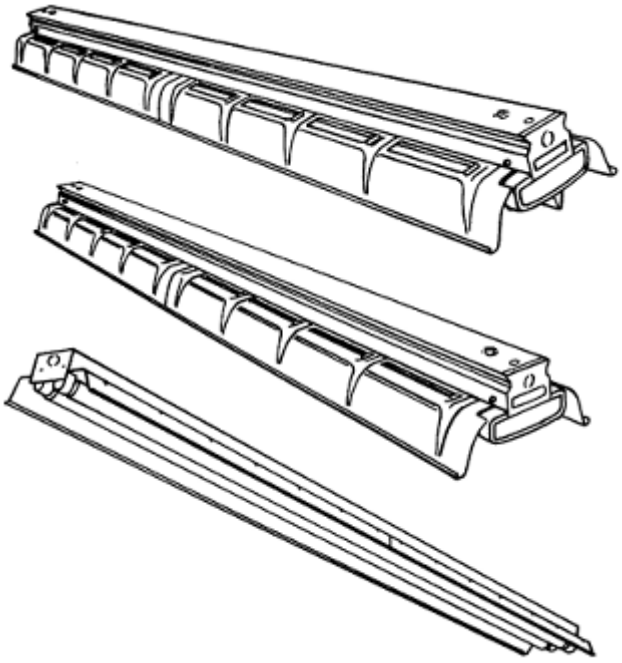


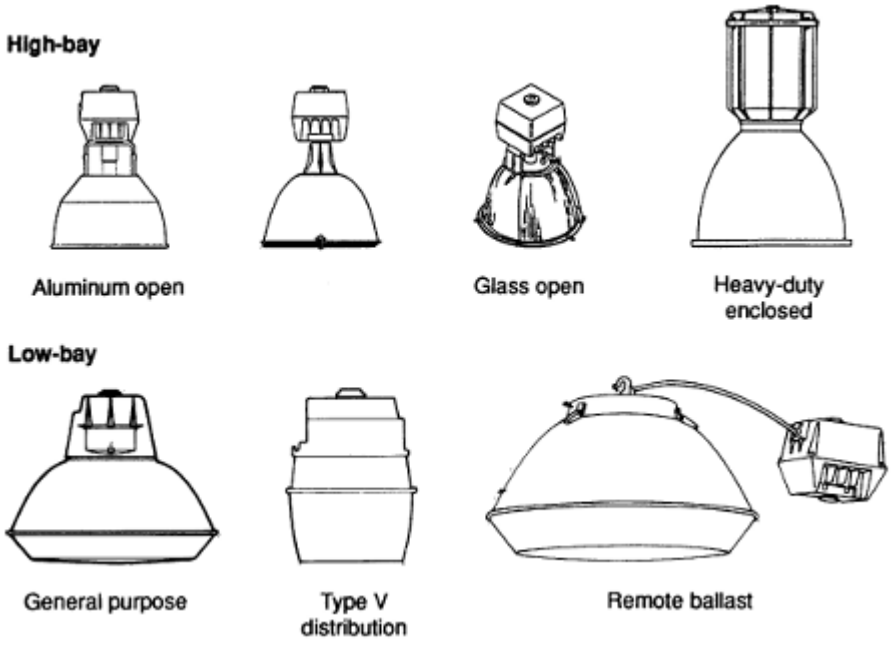

High-bay
Aluminum open
Glass open
Heavy-duty enclosed
Low-bay
General purpose
Type V distribution
Remote ballast

Fig.1

Lighting calculations

UNITS AND QUANTITIES

Quantity	*Quantity symbol*	*Unit*	*Unit Symbol*
Luminous intensity	I	Candela	cd
Luminous flux	Φ	Lumens	lm
Illuminance	E	Lux	lx
Luminance	L	Candela square metre	cd/m^2
Luminous efficacy		Lumens per watt	lm/W

Methods of Lighting Calculation

In general , there are three methods of lighting calculations :

- Inverse square law
- Cosine law
- Lumen method (most common)
- Reflective index method

Inverse square law

Consider Rays of light falling upon a surface from some distance *d* will illuminate that surface with an illuminance of say 1 lx. If the distance *d* is doubled as shown in Fig. 2, the illuminance of 1 lx will fall over four square units of area. Thus the illumination of a surface follows the **inverse square law** .

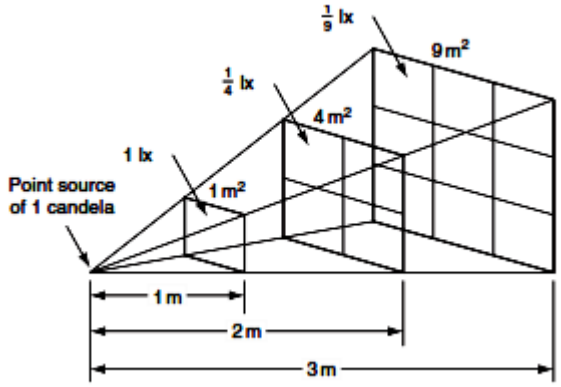
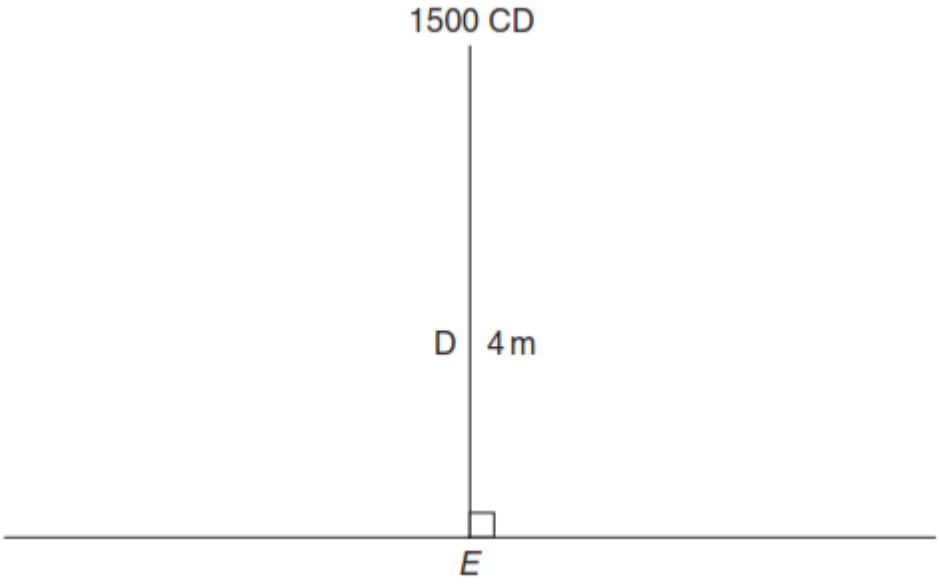


Fig.2.

When using the inverse square law, the distance used in the measurement is from the light source to a point directly below it. When a lamp is suspended above a surface, the illuminance at a point below the lamp can be calculated:

$$\text{Illuminance } E = \frac{(I)\ \text{candela}}{\text{distance}^2}\ \text{lux}$$
$$= \frac{I}{\text{d}^2}$$

EXAMPLE 1 A luminaire producing a luminous intensity of 1500 candela in all directions below the horizontal, is suspended 4m above a surface. Calculate the illuminance produced on the surface immediately below the luminaire.



$$E = \frac{I}{d^2}$$
$$= \frac{1500}{4^2}$$
$$= 93.75 \text{ lux}$$

EXAMPLE 2 If the luminaire in Example 1 is raised by 1m, what would the new illuminance be at the point immediately below the surface?

$$E = \frac{1500}{(4+1)^2}$$
$$= \frac{1500}{5^2}$$
$$= 60 \text{ lux}$$

COSINE LAW

The illumination of surface A in Fig. 3 will follow the inverse square law described above. If this surface were removed, the same luminous fl ux would then fall on surface B. Since the parallel rays of light falling on the inclined surface B are spread over a larger surface area, the illuminance will be reduced by a factor θ, and therefore:

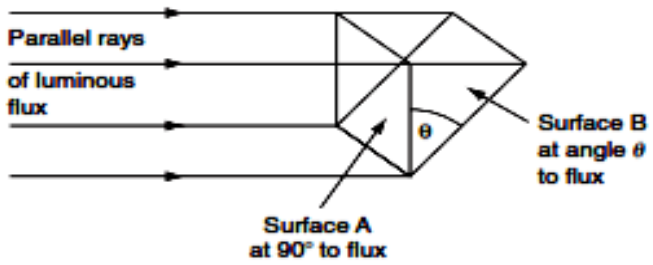
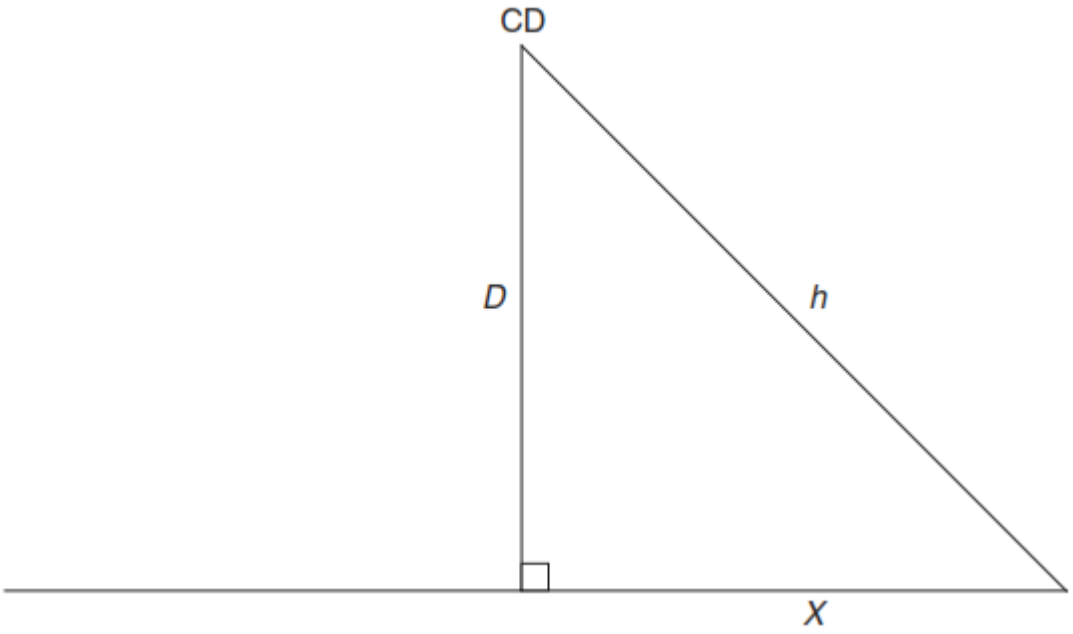


Fig.3

When using the cosine law, the distance used is from the light source measured at an angle to the point at which the lux value is required. When a lamp is suspended above a horizontal surface, the illuminance (E) at any point below the surface can be calculated.

$$E = \frac{I}{h^2} \cos \phi$$



To calculate h^2 (distance from lamp)

$$h^2 = d^2 + x^2$$

To calculate $\cos\phi$

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Solution

Calculate h^2 using Pythagoras.

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$$= 2.2^2 + 2.5^2$$
$$h^2 = 11.09$$

Calculate h

$$= \sqrt{h^2}$$
$$= 3.33$$

Calculate $\cos\phi$ using pythagoras

$$= \frac{d}{h}$$
$$= \frac{2.2}{3.33}$$
$$= 0.66$$
$$E_Q = \frac{1500}{11.09} \times 0.66$$
$$= 89.26 \text{ lux}$$

EXAMPLE 2 Two lamps are suspended 10m apart and at a height of 3.5 m above a surface (Figure 2). Each lamp emits 350cd. Calculate.
(a) the illuminance on the surface midway between the lamps,
(b) the illuminance on the surface immediately below each of the lamps.

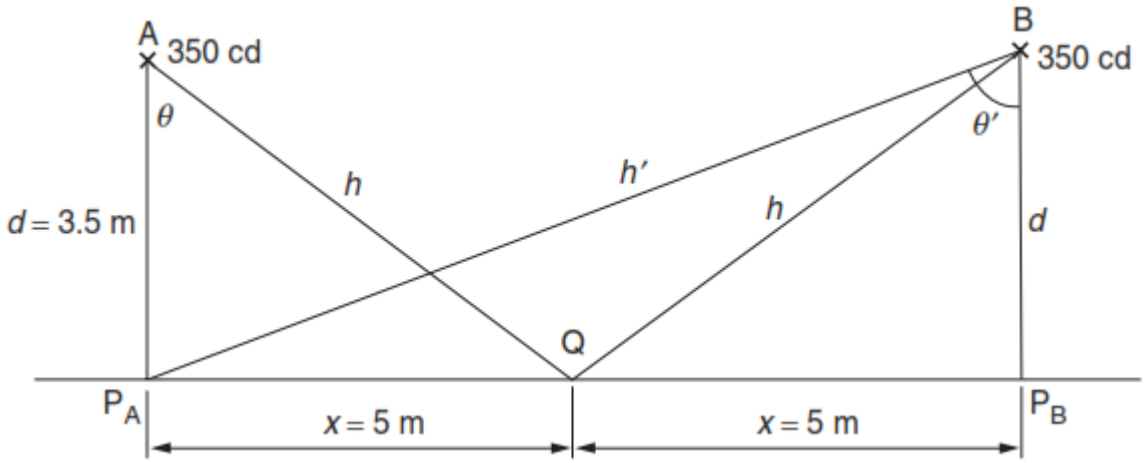


Fig.2

Solution :

(a) For one lamp, the illuminance at Q is

$$E_Q = \frac{I}{h^2}\cos\theta$$

$$= \frac{350}{3.5^2 + 5^2} \times \frac{3.5}{\sqrt{(3.5^2 + 5^2)}}$$

$$= \frac{350}{12.25 + 25} \times \frac{3.5}{\sqrt{(12.25 + 25)}}$$

$$= \frac{350}{37.25} \times \frac{350}{\sqrt{37.25}}$$

$$= 5.388\,\text{lx}$$

The illuminance from two lamps is double that due to one lamp, since the conditions for both lamps are identical. Thus total illuminance at Q = 2 × 5.388 = 11.8 lx

(b) At P_A below lamp A, the illuminance due to lamp A is

$$\begin{aligned} E_{P_A} &= \frac{I}{d^2} \\ &= \frac{350}{3.5^2} \\ &= 28.57 \text{ lx} \end{aligned}$$

In calculating the illuminance at PA due to lamp B, we have a new distance *h'* , a new distance *x'* , and a new angle *θ'* to consider.

$$\begin{aligned} x' &= 2x \\ &= 10 \\ (h')^2 &= 3.5^2 + 10^2 \\ &= 112.25 \\ \therefore \quad (h') &= 10.59 \end{aligned}$$

$$\begin{aligned} \cos\theta' &= \frac{d}{h'} \\ &= \frac{3.5}{10.59} \\ &= 0.331 \end{aligned}$$

$\therefore$ illuminance at P_A due to lamp B is

$$E_{P_B} = \frac{350}{112.25} \times 0.331$$
$$= 1.013$$

$$\text{Total illuminance at } P_A = 28.57 + 1.013$$
$$= 29.61 \text{ lx}$$

and, as the conditions at PB are the same as those at PA , this will also be the illuminance below lamp B.

Problems

1. A lamp emitting 450 cd in all directions is suspended 3m above the floor. The illuminance on the floor immediately below the lamp is

(a) 150 lx **(b)** 1350 lx **(c)** 50 lx **(d)** 0.02 lx

2. If the lamp of question 7 is reduced in height by 0.5 m, the illuminance produced immediately below it is

(a) 72 lx **(b)** 36.7 lx **(c)** 129 lx **(d)** 180 lx

Lighting design and calculations

THE LUMEN METHOD

This method is also called: Photometrical Computation and mostly used for interior lighting calculation

To determine the total number of luminaires required to produce a given illuminance by the lumen method we apply the following formula:

Total number of luminaires (N) required to provide a chosen level of illumination (E) at a given surface is .

$$N = \frac{E\ (lx - \ required) x\ Area\ (m^2)}{lumen\ from\ each\ luminaire\ xUFxMF}$$

where

- E = the illuminance level is chosen after consideration of the IES code,
  the area is the working area to be illuminated, the lumen output of each luminaire is that given in the manufacturer's specification and may be found by reference tables.
- MF is maintenance or (the light loss LLF) factor. This factor depends on the maintenance staff of the building, but in general it is taken as 0.8 -0.9.
- Utilization factor (UF)
  The light flux reaching the working plane is always less than the lumen output of the lamp since some of the light is absorbed by the various surface textures.
  The method of calculating the utilization factor (UF) is detailed in lighting design books, although lighting manufacturers' catalogues give factors for standard conditions. The UF is expressed as a number which is always less than unity; a typical value might be 0.9 for a modern office building.

Example 1

It is proposed to illuminate an electronic workshop of dimensions 9 x 8 x3 m to an illuminance of 550 lx at the bench level. The specification calls for luminaires having one 1500 mm 65 W fluorescent natural tube with an initial output of 3700 lumens. Determine the number of luminaires required for this installation when the UF and MF are 0.9 and 0.8, respectively.

The number of luminaire required (N)

$$N = \frac{E\ (lx) x\ Area\ (m^2)}{lumen\ from\ each\ luminaire\ xUFxMF}$$

$$N = \frac{550\ x\ 9x8}{3700\ x0.9x0.8} = 14.86$$

Therefore 15 luminaires will be required to illuminate this workshop to a level of 550 lx.

- Other factors that may be taken into consideration when using the lumen method are :

1. Room Index: this includes

- Room dimensions:
  (i) Length (a)

  (ii) Width (b)

  (iii) Height (h)

- Useful Height - H_k.

This can be calculated as:

$h_k = h - h_d$ or $h_k = h - h_d - h_v$ ……. (1)

where :

h_k = useful height

h = room height

h_d = height of working area, usually taken as : 0.85 m

h_v = height of illumination unit hanging from the ceiling , measured in (m).

$$Room\ \ Index(k) = \frac{a.b}{h_k(a+b)} \qquad (2)$$

2. The reflection factor - ρ

This means the light reflected from ceilings, walls and floors which and depends on the colours, type of floor and ceilings. Table -1 gives the reflection coefficient for various materials.

Reflection coefficient P.U.	Material
0.50	الطابوق (الطوب) الاصفر
0.40	الطابوق(الطوب) الغامق
0.30	الطابوق(الطوب) الاحمر
0.27	الآلسمنت
0.55	الكونكريت (الباطون)
0.40	حجر الكرانيت
0.45	المرمر (الرخام) الابيض
0.70	الصبغ (الابيض الثلجي)
0.5 -0.3	الصبغ الفاتح اللون للجدران
0.70	الزجاج النقي
0.40	الإسفلت
0.1	الكاشي (البلاط) الاسود
0.70	الكاشي الموزائيك الابيض
0.30	الكاشي الموزانيك الاحمر
0.20	الكاشي الموزانيك الاسود والابيض
0.1	الرخام الغامق للارضيات

The reflection coefficients ρ can be used to determine the utilization factor UF for any luminaire from the manufacturers catalogues when the room index is calculated. For example, Table -2 gives the utilization factor UF for a fluorescent luminaire with single 40W lamp and prismatic diffuser1300 mm length for different values of the room reflection coefficients: C – ceiling reflection, W- wall reflection, F- floor reflection. If these values are: (0.5, 0.5, 0.2) and the room index is calculated to be 1.50, then the UF = 0.52.

Table -2

Utilisation factor for fluorescent luminare with single 40W lamp and prismatic diffuser 1300 mm length.

Room Reflection			Room Index								
C	W	F	.75	1.00	1.25	1.50	2.00	2.50	3.00	4.00	5.00
.70	.50	.20	.44	.50	.56	.60	.65	.69	.72	.75	.77
	.30		.38	.44	.50	.54	.60	.64	.68	.72	.74
	.10		.33	.40	.46	.50	.56	.61	.64	.69	.72
.50	.50	.20	.39	.44	.49	.52	.57	.60	.62	.65	.67
	.30		.34	.40	.44	.48	.53	.56	.59	.62	.64
	.10		.30	.36	.41	.44	.50	.53	.56	.60	.62
.30	.50	.20	.34	.39	.42	.45	.49	.51	.53	.55	.57
	.30		.30	.35	.39	.42	.46	.49	.51	.53	.55
	.10		.27	.32	.36	.39	.44	.47	.49	.52	.54
.00	.00	.00	.22	.26	.29	.31	.34	.36	.38	.40	.41
			→				UF	←			

Note: The reflection coefficients for a standard room are: (0.7, 0.5, 0.2)

Table -3 gives the maintenance factors for different types of rooms.

Table -3 Maintenance factor

Room classification	**Lamp maintenance factor**	**Maintenance factor for dirty lamp**	**Total maintenance factor**
very clean	0.09	0.85	0.85-0.9
clean	0.9	0.9	0.8
average	0.9	0.8	0.7
dirty	0.9	0.7	0.6

Example 2

It is proposed to illuminate a class room of dimensions 6 x 8 x 2.85 m to an illuminance (E) of 400 lx at the bench level. The specification calls for luminaires having one 1050 mm 40 W fluorescent natural tube with an initial output of 3200 lumens with white metal base and prismatic plastic diffuser (its UF is given in Table -2) . Determine the number of luminaires required for this installation when the MF is 0.7, respectively. The reflection coefficients are: (C= 0.70, W= 0.3, F=0.2)

Solution

From the room dimension we can calculate the room index (*k*)

assuming the working table height is 0.85 m. Hence,

$$h_k = 2.85\text{-}0.85 = 2\text{m}$$

$$Room\ \ Index(k) = \frac{a.b}{h_k(a+b)}$$

$$k = \frac{6\,x\,8}{2\,x\,(6+8)} = 1.71$$

From Table -2 , UF = 0.57

$$N = \text{No. of luminaires} = \frac{lumen\ required\ x\ Area(m^2)}{lamp\ lumen\ x\ U.F\ x\ M.F}$$

$$N = \frac{400\,x\,48}{3200\,x\,0.7\,x\,0.57} = 14.58 \approx 15$$

Since 15 luminaire are large number that can be installed in the ceiling, so we suggest to use luminare with 2x40 W fluorescent lamps with prismatic diffuser. Hence, the number of luminaire required will be,

$$\frac{15}{2} = 7.5 \Rightarrow 8 \quad \text{luminaire}$$

Luminaires distribution:

Distance between two adjacent luminaire s is

$$= \frac{Room\ length}{No.of\ luminaire\ in\ a\ single\ row} = \frac{8}{4} = 2m$$

Distance between the luminaire and its adjacent wall = (½ to ⅓)x(room height):

or $\frac{2.85}{2}$ = 1.425 ≈ 1.50 m

Note: Usually we take the factor ½ when the dimensions of the room are such that the ratio of the length to the width is less than 1.6, otherwise we take the factor of ⅓ .

The distribution of the luminaires are shown in Fig.A

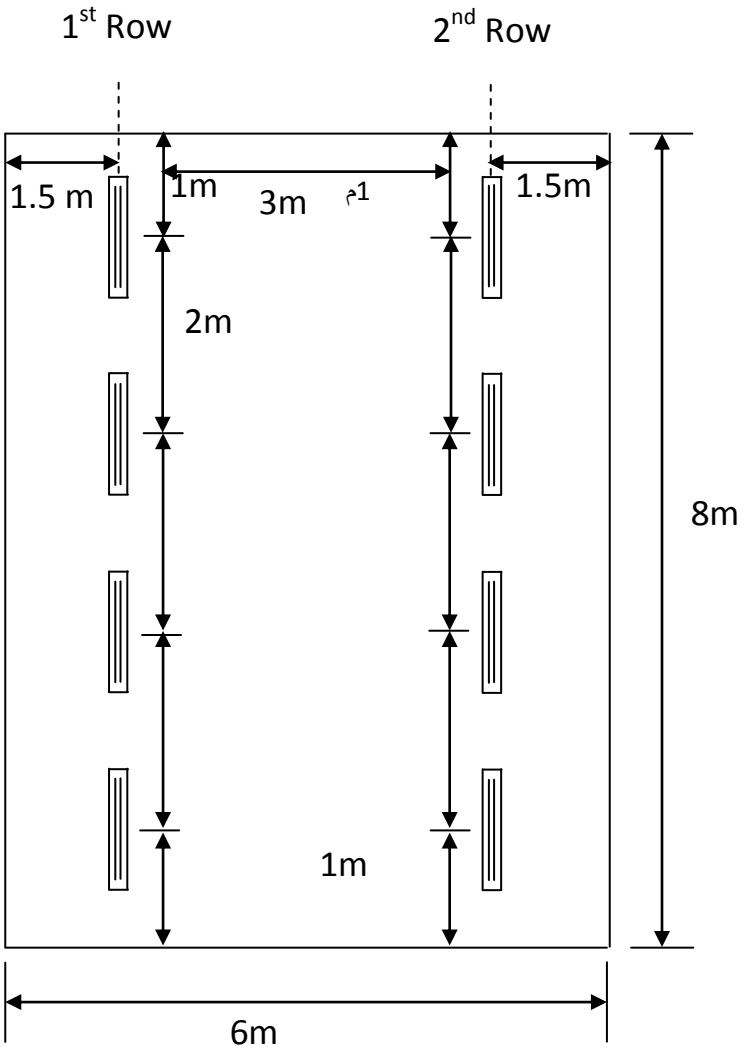


Fig.A Luminaires distribution on room ceiling

Accessories

INTRODUCTION

From the user's point of view the electricity service in a building consists of socket outlets, light switches, power points, clock connectors, cooker control units and similar outlets. Such fittings are collectively known as accessories.

SOCKET OUTLETS

A socket outlet is the correct name of what is popularly known as a power point. It is a female socket connected to the power wiring in the building and will accept the male plug attached at the end of the flexible wire of an appliance such as a vacuum cleaner, electric fire or music centre.They are rated at 2 A, 5 A.13A and 15A, the spacing of the pins and sockets being different for the different ratings. This makes sure that a plug of one rating cannot be inserted, even wilfully, into a socket of a different rating. Plugs and sockets rated at 2 and 5 A are available in both two- and three-pin versions, but those of 15 A rating are made only with three pins.

Types of Domestic plugs and sockets

- Type A (North America/Japanese 2-pin)

- Type B (American 3-pin)

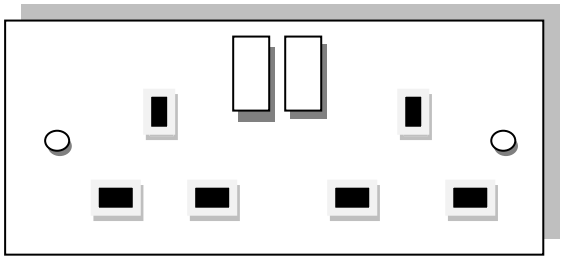
- Type C (European 2-pin)

- (Type D – German 2-pin)

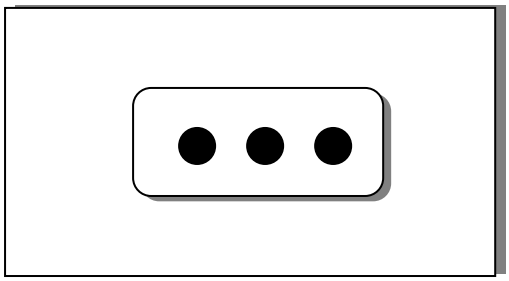
- Type E (French 2-pin , female earth)

- Type F (British 3- pin)

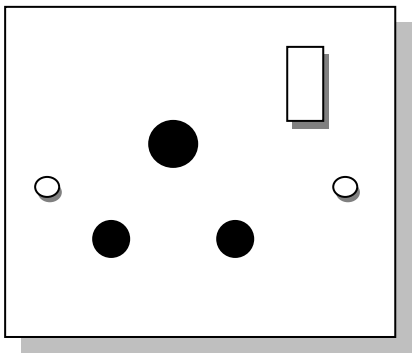
- Duplex British 3 – pin (type –F)



- Type G (Danish 3-pin)



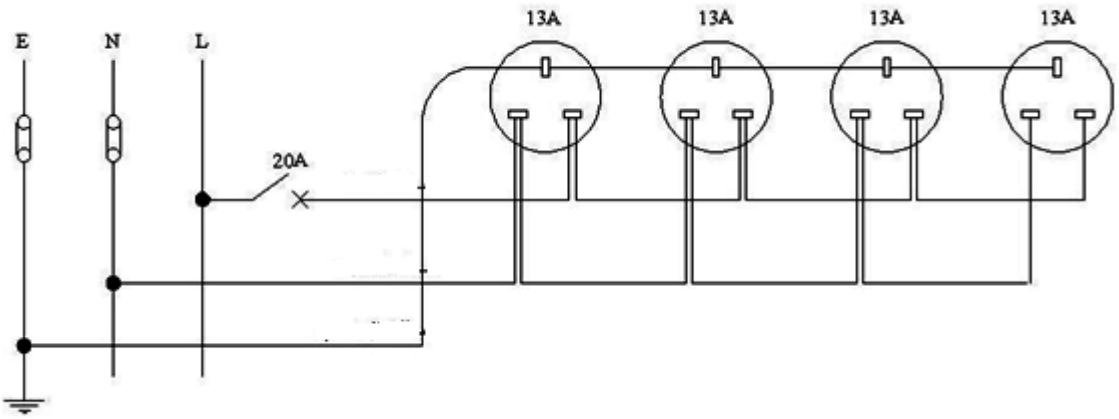
- BS 546 (15 A/250 V earthed)



Type of connection of socket outlets circuits

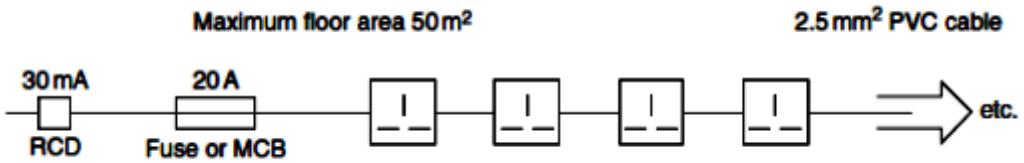
1. Radial circuit

- In radial circuit we can connect 4-6, 13A socket outlets protected by 20A -25A mcb.



Radial circuit

It is required to connect 30mA RCD (residual current device) for each circuit as shown in Figure below:



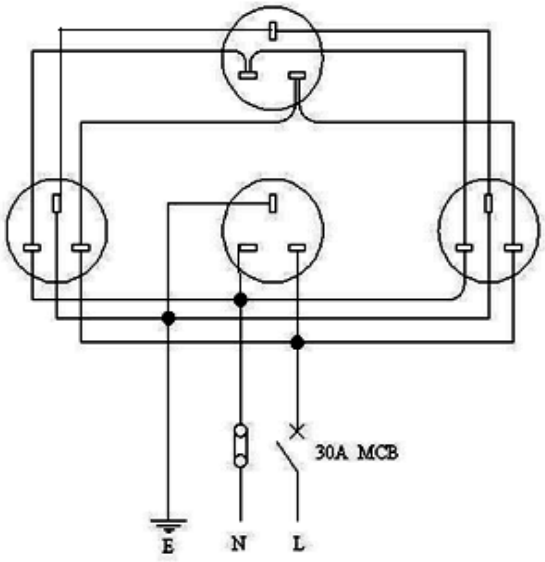
Radial circuit with RCD

2. Ring circuit

Ring circuit is used to increase reliability of the system and to reduce the number of circuits and circuit breakers in the final distribution board and also to serve larger area with socket outlets.

A ring circuit with 30A protective device can serve

Area 90 – 100 m^2 , i.e., connecting about 16 sixteen ,13A socket outlet with 2.5 mm2 PVC cable.



Ring connected socket outlets

- Ring circuits fed from systems where no earth terminal is provided by the Electricity Supply Company (TT systems) must be protected by an RCD rated at 30 mA, In all installations, a socket intended to feed equipment outdoors must be individually protected by a 30 mA RCD.
- Where a socket is mounted on a vertical wall, its height above the floor level orthe working surface level level must be such that mechanical damage is unlikely. A minimum mounting height of 150 mm is recommended.

The fused plug

- In many situations there is a need for socket outlets to be closely spaced so that they are available to feed appliances and equipment without the need to use long and dangerous leads. For example, the domestic kitchen worktop should be provided with sockets to feed the many appliances (deep fat fryer, kettle, sandwich toaster, carving knife, toaster, microwave oven, coffee maker, and so on) which are likely to be used. Similarly, in the living room we need to supply television sets, video recorders, stereo players, table lamps, room heaters, etc. In this case, more outlets will he needed to allow for occasional rearrangement of furniture, which may well obstruct access to some outlets.
- Thus a ring circuit protected by a 30 A or 32 A device may well feed twenty socket outlets. It follows that judgment must be used

to make as certain as possible that the total loading will not exceed the protective device rating, or its failure and inconvenience will result. Two basic steps will normally ensure that a ring circuit is not overloaded.

- **1.** Do not feed heavy and steady loads (the domestic immersion heater is the most obvious example) from the ring circuit, but make special provision for them on separate circuits.
- **2.**-Make sure that the ring circuit does not feed too great an area. This is usually ensured by limiting a single ring circuit to sockets within an area not greater than one hundred square meters.

A fused plug and socket to BS 1363 is shown in Fig.1 below.

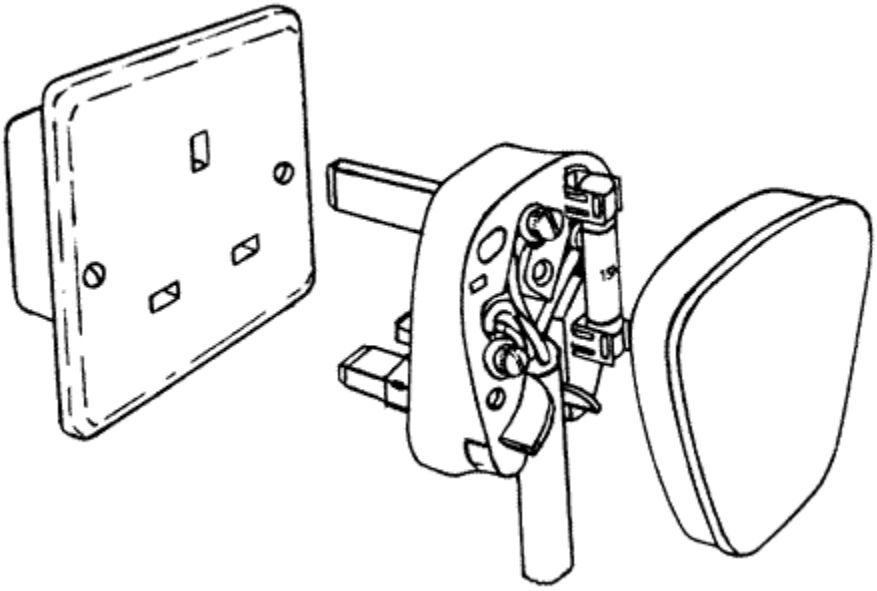


Fig.1 Plug and socket to BS 1363

A plug to BS 1363 without a fuse is not available. The circuit protection in the distribution board or consumer's unit covers the circuit wiring, whilst the fuse in the plug protects the appliance and its cord as shown in Fig .2. In this way, each appliance can be protected by a suitable fuse, for example, a 3 A fuse for a table lamp or a 13 A fuse for a 3 kW fan heater.

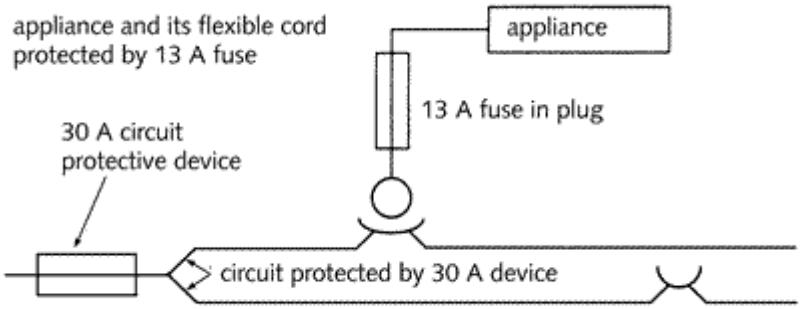


Fig .2 Principle of appliance protection by plug fuse.

- **15A and 16A socket outlets are each considered as one power point which must be protected by one separate circuit breaker (usually 30A rating) . No diversity factor is taken.**

2. Industrial (heavy duty) socket outlets

There is no reason at all to prevent the installation of BS 1363 (13 A) socket outlets in industrial situations. Indeed, where light industry, such as electronics manufacture, is concerned, these sockets are most suitable. However, heavy duty industrial socket outlets are available, either in single-phase or 3-phase. These are shown in Fig.3 below.

Fig.3 Industrial (heavy duty) socket outlets

VOLTAGE DROP IN RING CIRCUITS

Sometimes it is necessary to calculate the voltage drop occurring in a ring circuit. The method to use is illustrated by Example 1 if the loads taken from the points of utilisation and the cable lengths between those points are known.

Example 1

Figure 4 (a) shows a single-phase ring circuit wired in 2.5 mm^2 core (with cpc) 70ºC pvc-insulated and sheathed cable. The figure gives the loads taken from each point of utilisation.

The first stage is to determine the current distribution and as shown in Figure 4(b) a current given by I_x A is taken to flow in the first section, (I_x - 5)A in the second section, and so on.

If the resistance per metre of the phase conductor is denoted by 'r' then:

$$I_x 6r + (I_x - 5)4r + (I_x - 15)3r + (I_x - 20)6r + (I_x - 25)8r + (I_x - 30)4r = 0$$

I_x r (6 + 4 +3 + 6 + 8 + 4) – r (20 + 45 + 120 + 200 + 120) = 0

I_x =16.29A

The current distribution therefore is as shown in Figure 4(c) and it is now possible to calculate the voltage drop.

This is given by:

[(16:29 x 6) + (11:29 x 4)

+ (1:29 x 3)] x $\frac{\text{mV/A/m}}{1000}$ V

i.e.

$$\frac{146.8 \times \text{mV/A/m}}{1000} \text{ V}$$

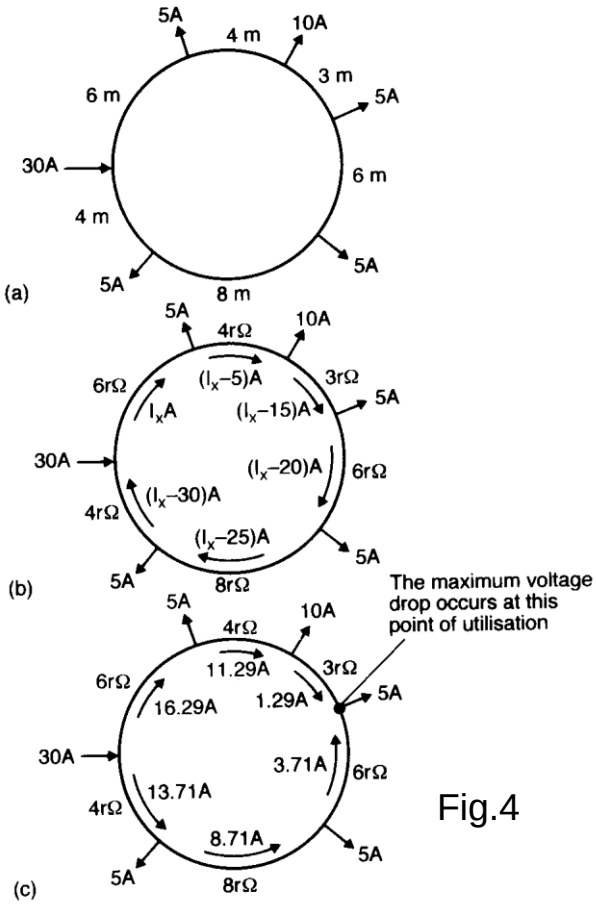


Fig.4

From Table (3-23) Column 3 the mV/A/m value is found to be

15.38 milliohms /A / m.
The voltage drop is therefore $\frac{146.8 \times 15.38}{1000} = 2.25\ V$

SWITCHES

A switch is used to make or interrupt a circuit. There are two types of switches:
1. Dolly operated switch.
2. Rocker operated switch.

The older type of switch mechanism was dolly operated. It is illustrated in Fig. 5. The moving contact was on a spring lever which was moved by a cam. Dolly operated switches have now been entirely superseded by rocker operated switches. This type is also illustrated in Fig. 5.
The advantages of the rocker switch are that it is easier to operate and that it is almost impossible to hold it half open, even deliberately.
Ratings:
Most manufacturers make switches in two standard capacities, the lower being rated at 5 amps and the higher at 10, 15 or 20 amps.

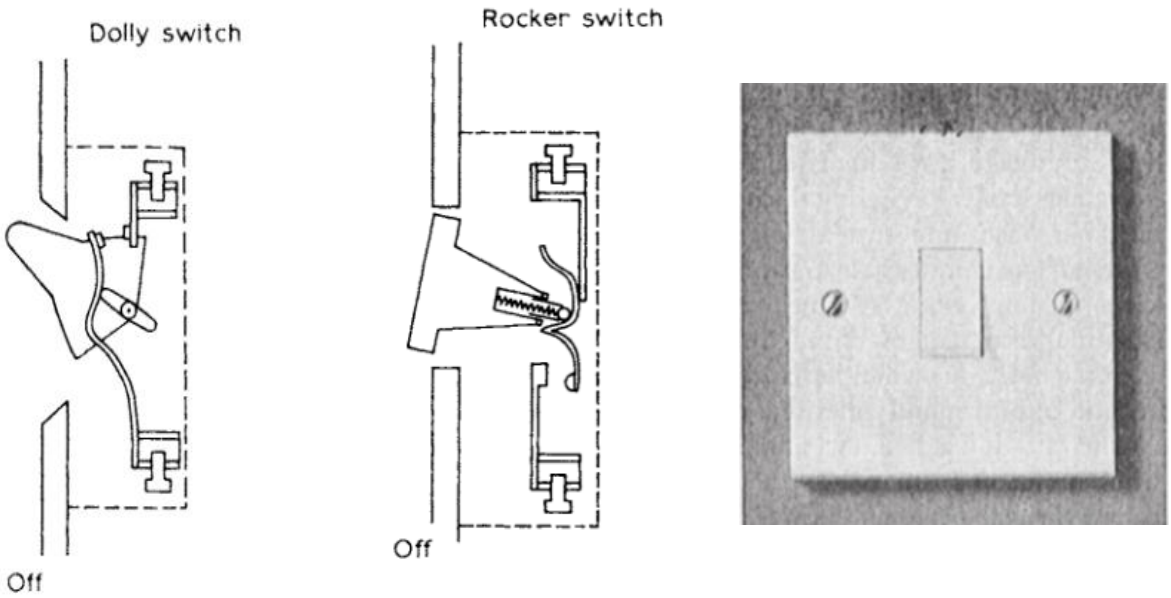


Fig.5

Boxes

The box is fixed to the wall, and the wires going to the switch are drawn into the box. After this the wires are connected to the mechanism. To carry out this operation the electrician must pull the wires away from the wall sufficiently to give himself room to work on the back of the mechanism. He then pushes the mechanism back into the box and the length of wire which he had to pull out from the wall becomes slack inside the box. It is therefore important that the box is large enough to accommodate a certain amount of slack wire at the back of the mechanism.

Standard boxes for recessing within a wall are 35 mm deep. There are also shallow boxes available which are 25 mm deep. These boxes are shown in Figure 6.

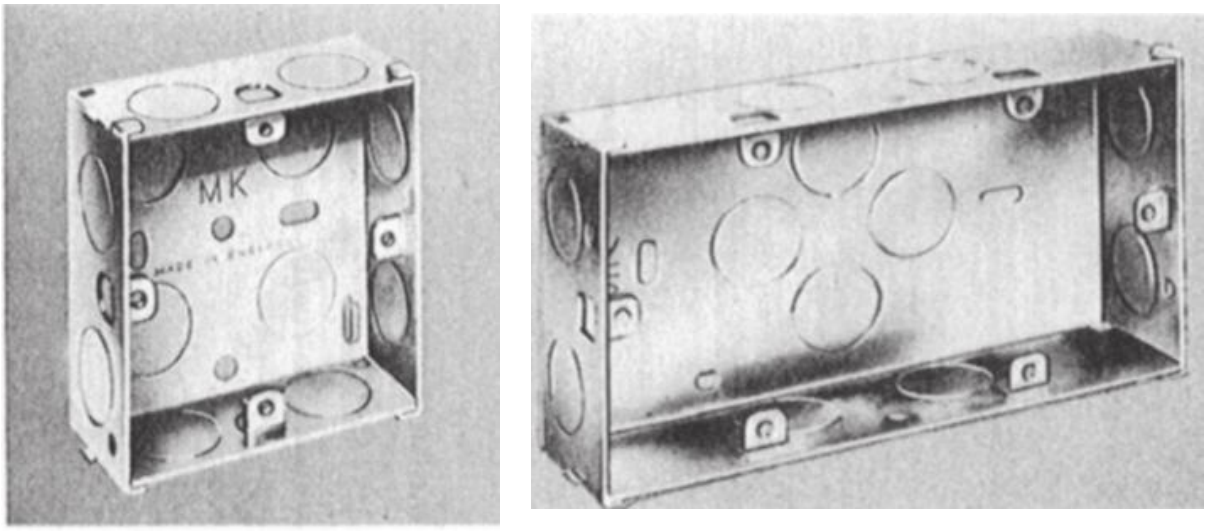


Fig.6

Protective Devices characteristics

1. Fuses

Fuses operate because the fuse element is the 'weak link' in the circuit, so that overcurrent will melt it and break the circuit. The time taken for the fuse link to break the circuit (to 'blow') varies depending on the type of fuse and on the characteristic of the device. The time/current characteristic of a typical fuse is shown in {Fig 1(a)}. Curves for other types and ratings of fuses are shown in {Figs 1 to 3.}. The figures are adapted from Appendix 3 of the BS 7671.

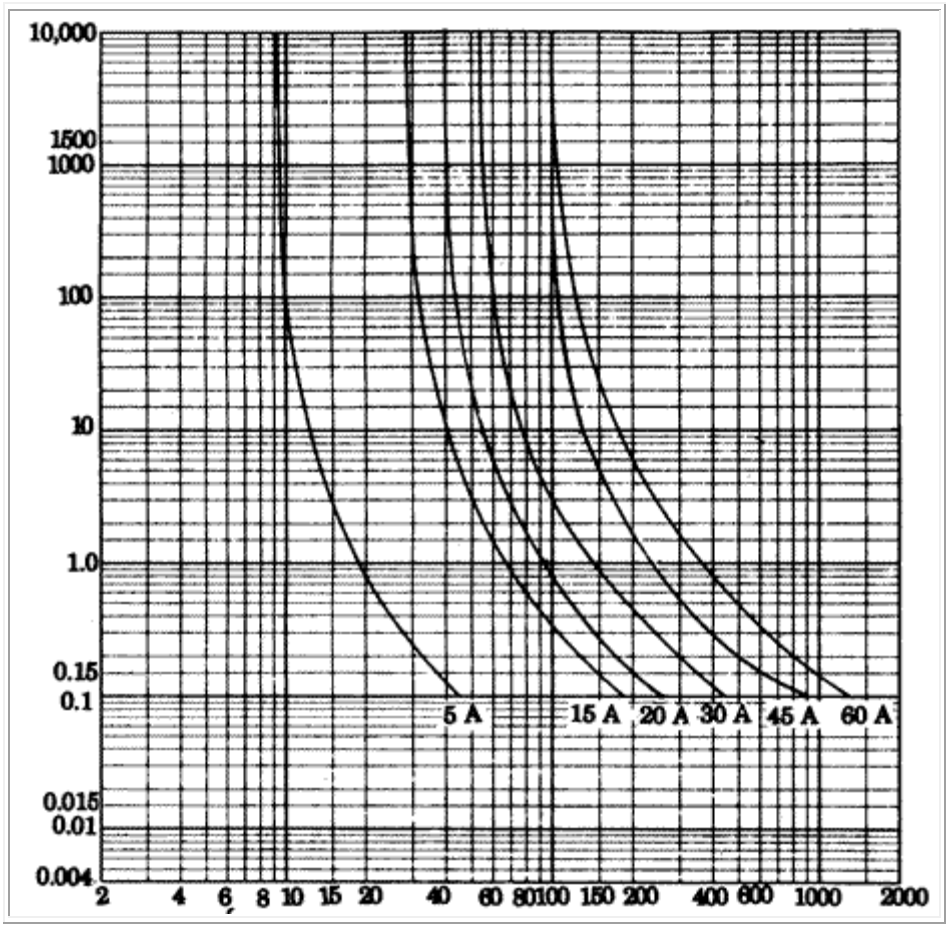


Fig .1 Time/current characteristics of semi-enclosed fuses to BS 3036.

Where the current carried is very much greater than the rated value (which is usually associated with a fault rather than with an overload) operation is usually very fast. For small overloads, where

the current is not much larger than the rated value, operation may take a very long time, as indicated.

A graph with linear axes would need to be very large indeed if the high current/short time and the low current/long time ends of the characteristic were to be used to read the time to operate for a given current. The problem is removed by using logarithmic scales, which open out the low current and short time portions of the scales, and compress the high current and long time portions.

This means that the space between two major lines on the axes of the graph represents a change of ten times that represented by the two adjacent lines. In other words, a very much increased range of values can be accommodated on a graph of a given size.

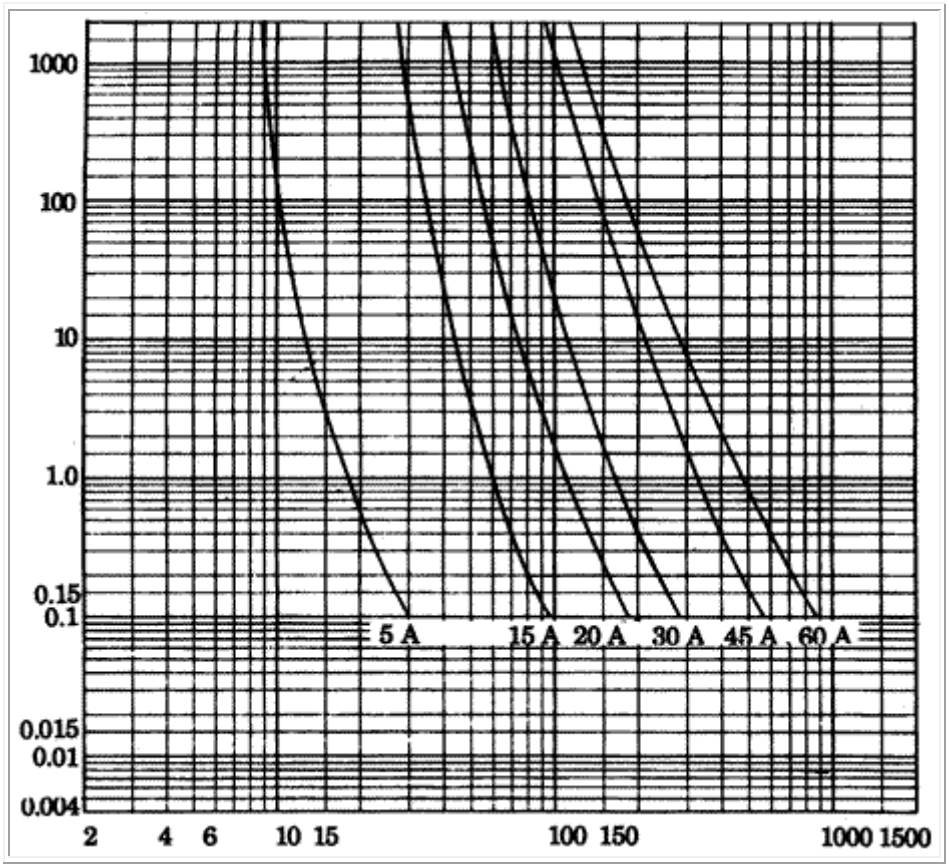


Fig 2. Time/current characteristics of cartridge fuses to BS 1361.

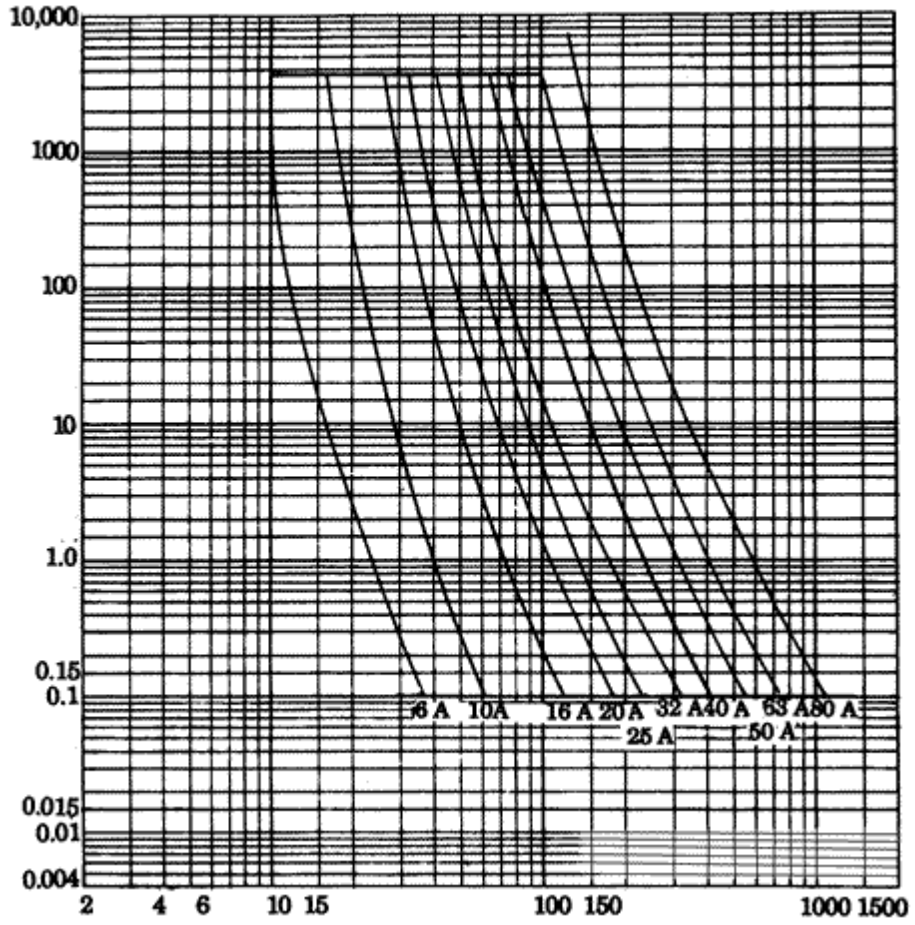


Fig 3 Time/current characteristics of cartridge fuses to BS 88 Part 2

Rewirable (semi-enclosed) fuses to BS 3036 may still be used, but as they can easily have the wrong fuse element (fuse wire) fitted and have low breaking capacity, they are not recommended for other than small installations. Where used, they are subject to the derating requirements which are explained in, The diameter of copper wires for use as elements in such fuses is shown in Table 1.

Table 1 Sizes of tinned copper wire fuse elements (from [Table 53A] of BS 7671)	
Fuse element rating (A)	*Wire diameter (mm)*
3	0.15
5	0.20
10	0.35
15	0.50
20	0.60
25	0.75
30	0.85
45	1.25
60	1.53

2. Circuit breakers

Circuit breakers operate using one or both of two principles. They are:

1). Thermal operation relies on the extra heat produced by the high current warming a bimetal strip, which bends to trip the operating contacts,

2). Magnetic operation is due to the magnetic field set up by a coil carrying the current, which attracts an iron part to trip the breaker when the current becomes large enough.

It must be remembered that the mechanical operation of opening the contacts takes a definite minimum time, typically 20 ms, so there can never be the possibility of truly instantaneous operation. All circuit breakers must have an indication of their current rating.

Types of circuit breaker

There are many different technologies used in circuit breakers and they do not always fall into distinct categories. Types that are common in domestic, commercial and light industrial applications at low voltage (less than 1000 V) include:

- MCB (Miniature Circuit Breaker)—rated current not more than 100 A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers illustrated above are in this category.
- MCCB (Moulded Case Circuit Breaker)—rated current up to 1000 A. Thermal or thermal-magnetic operation. Trip current may be adjustable.
- ACB (Air circuit breaker) – rated current up to 4000 A .Thermal and magnetic operation. Trip current adjustable.

Miniature circuit breakers have fixed ratings but moulded case types can be adjusted.

There are many types and ratings of moulded case circuit breakers, and if they are used, reference should be made to supplier's literature for their characteristics. Miniature circuit breakers are manufactured in fixed ratings from 5 A to 100 A for some types,

Short circuit ratings for the newer types will be a minimum of 3 kA and may be as high as 25 kA.

The time/current characteristics of all types of circuit breakers are shown in Figs 4 to 6. .

For example, a Type C MCB has a multiple of 10 (from Table 2) so a 30 A device of this type will operate over the time range of 0.04 s to 5 s at a current of 10 x 30 A = 300 A.

Table 2 Operating time ranges and current multiples for MCBs over fixed current section of characteristic

MCB Type	*Range of operating times (s)*	*Current multiple of rating*
B	0.04 to 13	x5
C	0.04 to 5	x10
D	0.05 to 3	x20

Table 3 shows a comparison of the three main types of protective device in terms of cost, whilst Table 4 compares the available types of MCB.

Table 3 A comparison of types of protective device

Semi-enclosed fuses	*HBC fuses*	*Miniature circuit breakers*
Very low initial cost	Medium initial cost	High initial cost
Low replacement cost	Medium replacement cost	Zero replacement cost
Low breaking capacity	Very high breaking capacity	Medium breaking capacity

Fig .1 show that about 53 A is needed to ensure the operation of a 30 A fuse after 10,000 s, giving a ratio of 53/30 or 1.77. For re-wirable fuses, the Regulations require that the fuse current rating must not exceed 0.725 times the rating of the smallest cable protected. Considering the 30 A cable protected by the 32 A miniature circuit breaker above, if a rewirable fuse replaced the circuit breaker, its rating must not be greater than 0.725 x 30 or 21.8 A.

Table 4 Comparison of miniature circuit breaker types

Type	Will not trip in	Will trip in	Typical application
	100ms at rating	100ms at rating	
B	3 x	5 x	General purpose use (close protection)
C	5 x	10 x	Commercial and industrial applications with fluorescent fittings
D	10 x	50 x	Applications where high in-rush currents are likely (transformers, welding machines)

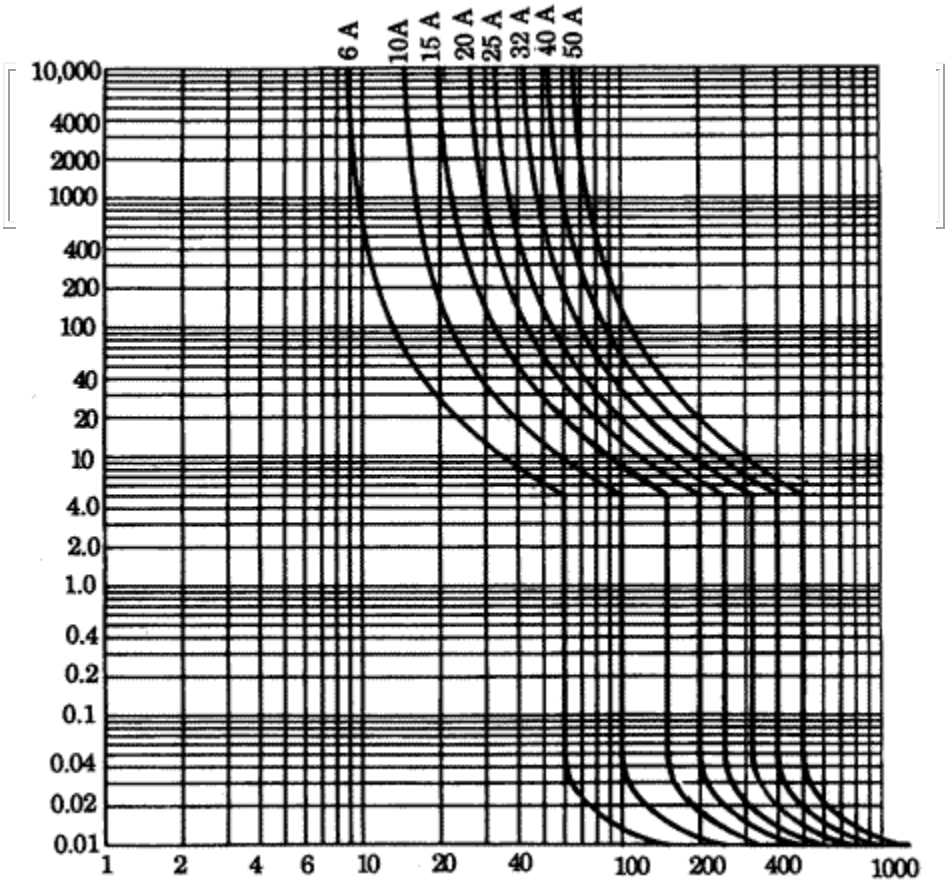


Fig 4 Time/current characteristics for some miniature circuit breakers Type C.

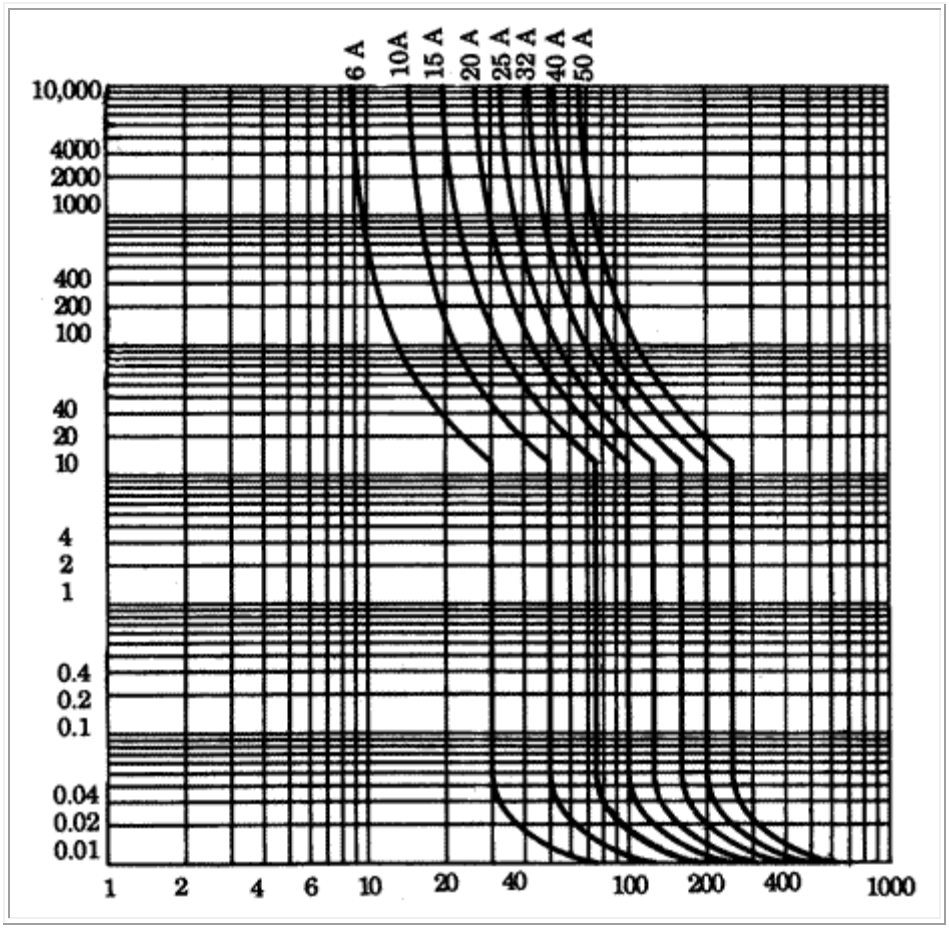


Fig 5 Time/current characteristics for some miniature circuit breakers Type B.

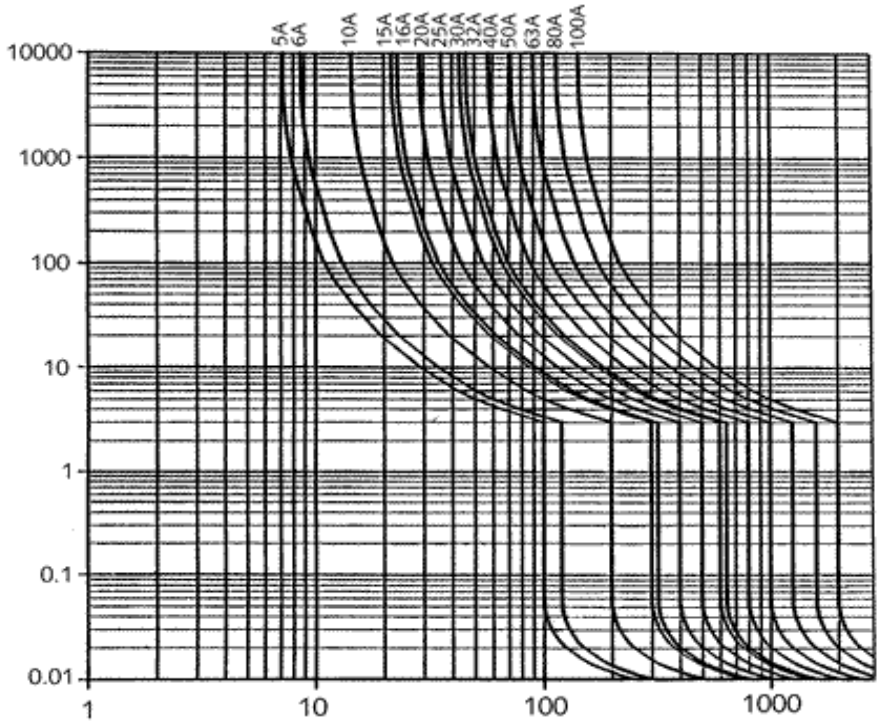


Fig. 6 Time/current characteristics for some miniature circuit breakers Type D.

Protecting conductors

The prime function of overload protection is to safeguard conductors and cables from becoming too hot. Thus the fuse or circuit breaker rating must be no greater than that of the smallest cable protected. Reference to the time/current characteristics of protective devices {Figs 1 to 6} shows that a significantly greater current than the rated value is needed to ensure operation.

Thus, the current at which the protective device operates must never be greater than **1.45** times the rating of the smallest cable protected. For example, consider a cable system rated at 30 A and protected by a miniature circuit breaker type C, rated at 32 A. Reference to Fig.5 shows that a prolonged overload of about 38 A will open the breaker after about 10^4 seconds (about two and a half hours). The ratio of operating current over rated current is thus 38/30 or 1.27, significantly lower than the maximum of **1.45**. All circuit breakers and HBC fuses listed in will comply with the Regulations as long as their rating does not exceed that of the smallest cable protected.

Semi-enclosed (rewirable) fuses do not operate so closely to their ratings as do circuit breakers and HBC fuses. For example, the time/current characteristics of {Fig .1} show that about 53 A is needed to ensure the operation of a 30 A fuse after 10,000 s, giving a ratio of 53/30 or 1.77. For rewirable fuses, the Regulations require that the fuse current rating must not exceed 0.725 times the rating of the smallest cable protected. Considering the 30 A cable protected by the 32 A miniature circuit breaker above, if a rewirable fuse replaced the circuit breaker, its rating must not be greater than 0.725 x 30 or 21.8 A.

Figure 7 shows part of a system to indicate how protection could be applied to conductors with reduced current carrying capacity.

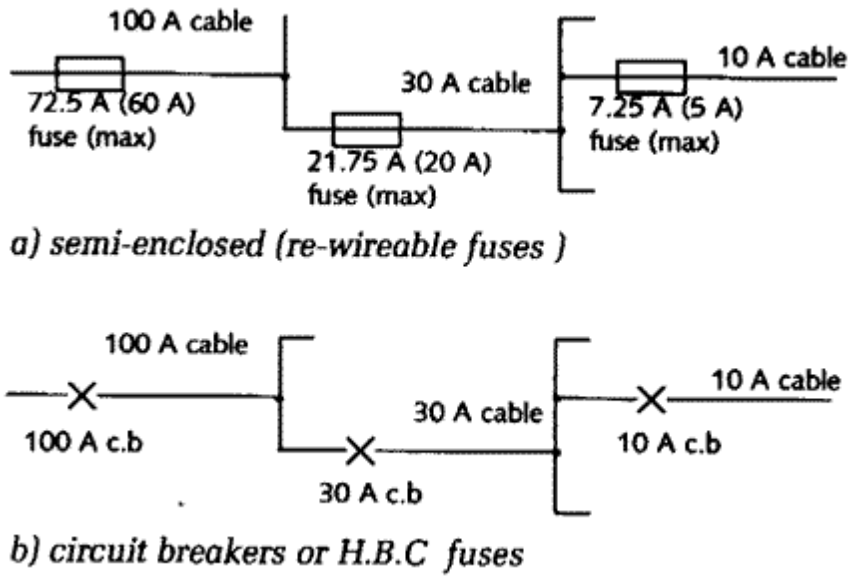


Fig.7 Position and rating of devices for overload protection

- In fact, the calculated fuse sizes for {Fig.7a)} of 72.5 A, 21.75 A and 7.25 A are not available, so the next lowest sizes of 60 A, 20 A and 5 A respectively must be used.
- It would be unwise to replace circuit breakers with semi-enclosed fuses because difficulties are likely to arise. For example, the 5 A fuse used as the nearest practical size below 7.25 A is shown in {Fig.1} to operate in 100 s when carrying a current of 10 A. Thus, if the final circuit is actually carrying 10 A, replacing a 10 A circuit breaker with a 5 A fuse will result in the opening of the circuit. The temptation may be to use the next semi-enclosed fuse size of 15 A, but that fuse takes nearly seven minutes to operate at a current of 30 A. Clearly, the cable could well be damaged by excessive temperature if overloaded.
- All phase conductors must be protected, but attention must be paid to the need to break at the same time all three line conductors to a three-phase motor in the event of a fault on one phase, to prevent the motor from being damaged by 'single-phasing'. Normally the neutral of a three phase system should not be broken, because this could lead to high voltages if the load is unbalanced. Where the neutral is of reduced size, overload protection of the neutral conductor may be necessary, but then a circuit breaker must be used so that the phases are also broken.

Earthing systems

What is earthing?

- The whole of the world may be considered as a vast conductor which is at reference (zero) potential.

- In the UK it is referred to this as 'earth' whilst in the USA it is called 'ground'.

- People are usually more or less in contact with earth, so if other parts which are open to touch become charged at a different voltage from earth a shock hazard exists.

- The process of earthing is to connect all these parts which could become charged to the general mass of earth, to provide a path for fault currents and to hold the parts as close as possible to earth potential. In simple theory this will prevent a potential difference between earth and earthed parts, as well as permitting the flow of fault current which will cause the operation of the protective systems.

- The standard method of tying the electrical supply system to earth is to make a direct connection between the two. This is usually carried out at the supply transformer, where the neutral conductor (often the star point of a three-phase supply) is connected to earth using an earth electrode. Figure 1 shows such a connection.

Types of earthing systems

1- TT systems

This arrangement covers installations not provided with an earth terminal by the Electricity Supply Company. Thus it is the method employed by most (usually rural) installations fed by an overhead supply. Neutral and earth (protective) conductors must be kept quite separate throughout the installation, with the final earth terminal connected to an earth electrode by means of an earthing conductor.

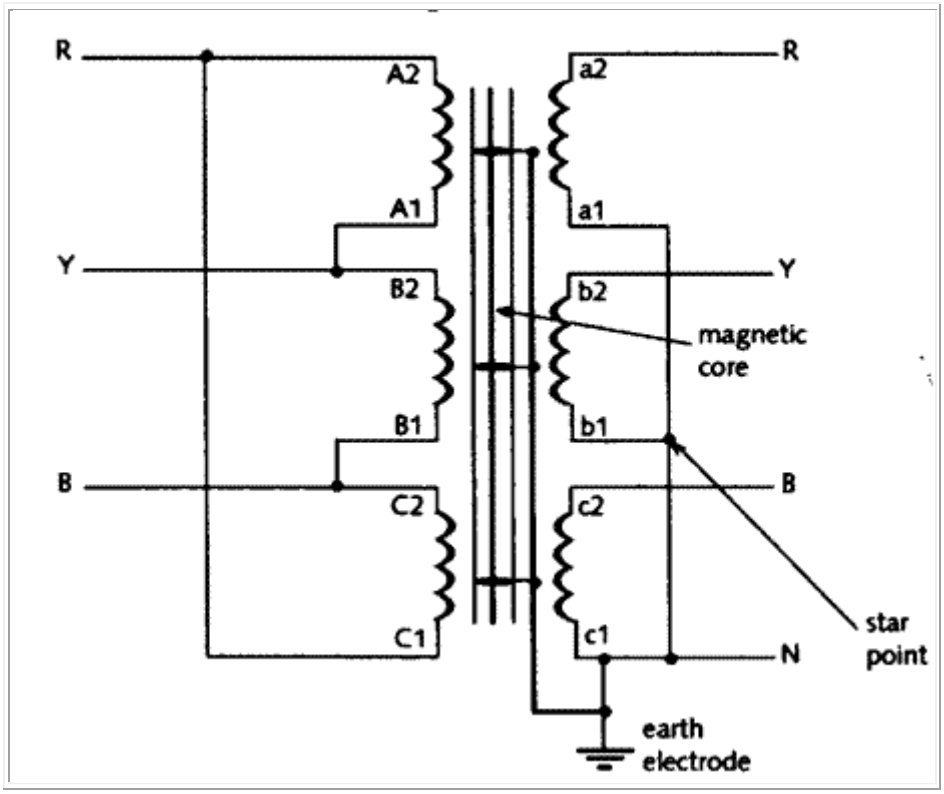


Fig .1 - Three-phase delta/star transformer showing earthing arrangements.

Effective earth connection is sometimes difficult. Because of this, socket outlet circuits must be protected by a residual current device (RCD) with an operating current of 30 mA . Fig. 2 shows the arrangement of a TT earthing system.

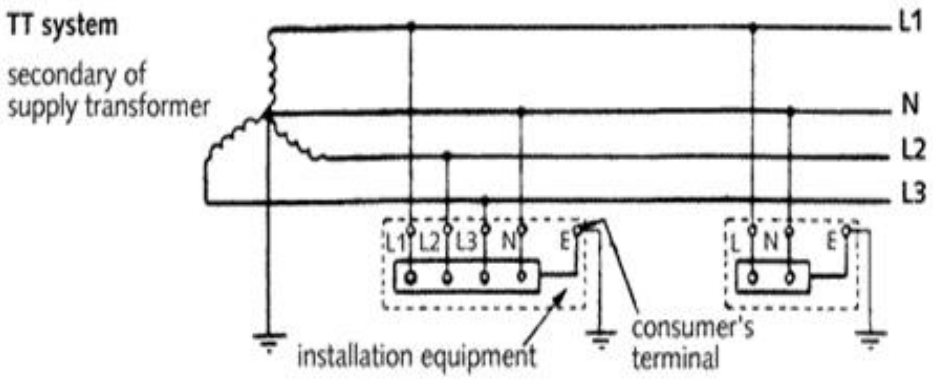


Fig.2 - TT earthing system

2 - TN-S system

This is probably the most usual earthing system in the world, with the Electricity Supply Company providing an earth terminal at the incoming mains position. This earth terminal is connected by the supply protective conductor (PE) back to the star point (neutral) of the secondary winding of the supply transformer, which is also connected at that point to an earth electrode. The earth conductor usually takes the form of the armour and sheath (if applicable) of the underground supply cable. The system is shown diagrammatically in {Fig.3}.

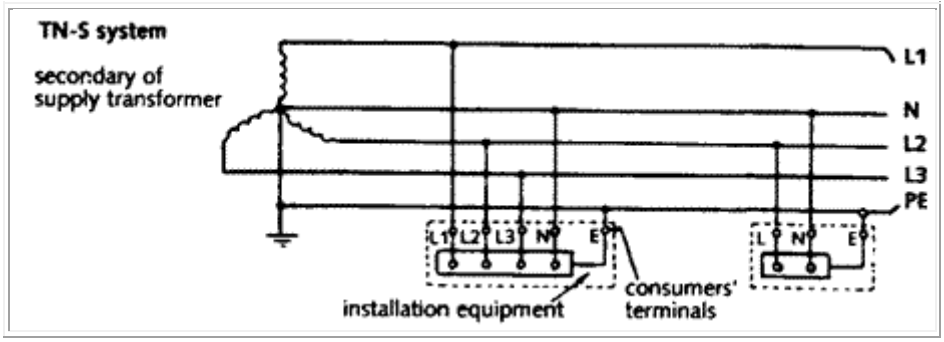


Fig.3 - TN-S earthing system

3 - TN-C-S system

In this system, the installation is TN-S, with separate neutral and protective conductors. The supply, however, uses a common conductor for both the neutral and the earth.This combined and neutral system is sometimes called the 'protective and neutral conductor' (PEN) the 'combined neutral and earth' conductor (CNE). The system, which is shown In Fig.4 is most usually protective multiple earth (PME) system.

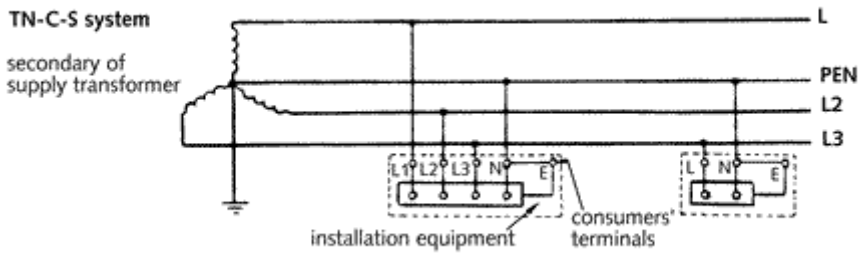


Fig.4 - TN-C-S earthing system - protective multiple earthin

4-TN-C system

This installation is unusual, because combined neutral and earth wiring is used in both the supply and within the installation itself. Where used, the installation will usually be the earthed concentric system, which can only be installed under the special conditions (mostly used in France).

5 - IT system

The installation arrangements in the IT system are the same for those of the TT system . However, the supply earthing is totally different. The IT system can have an unearthed supply, or one which is not solidly earthed but is connected to earth through a current limiting impedance.IT system is shown in Fig.5.

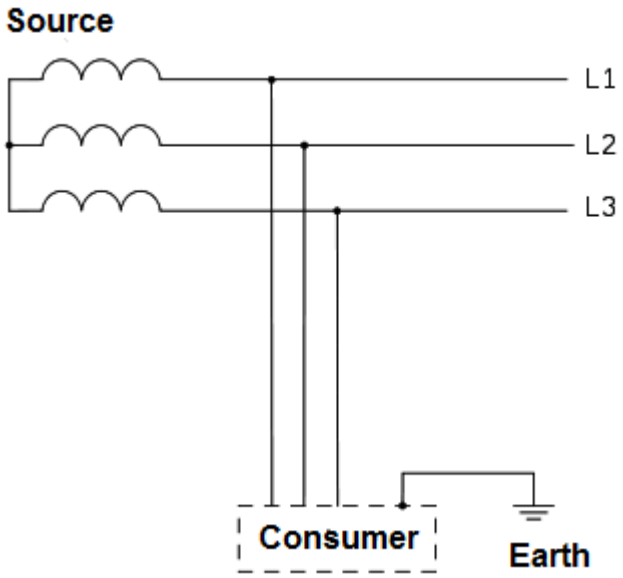


Fig.5 - IT earthing system

Principle of earthing system

- The path followed by fault current as the result of a low impedance occurring between the phase conductor and earthed metal is called the **earth fault loop**. Current is driven through the loop impedance by the supply voltage.
- The extent of the earth fault loop for a TT system is shown in {Fig .6}, and is made up of the following labelled parts.

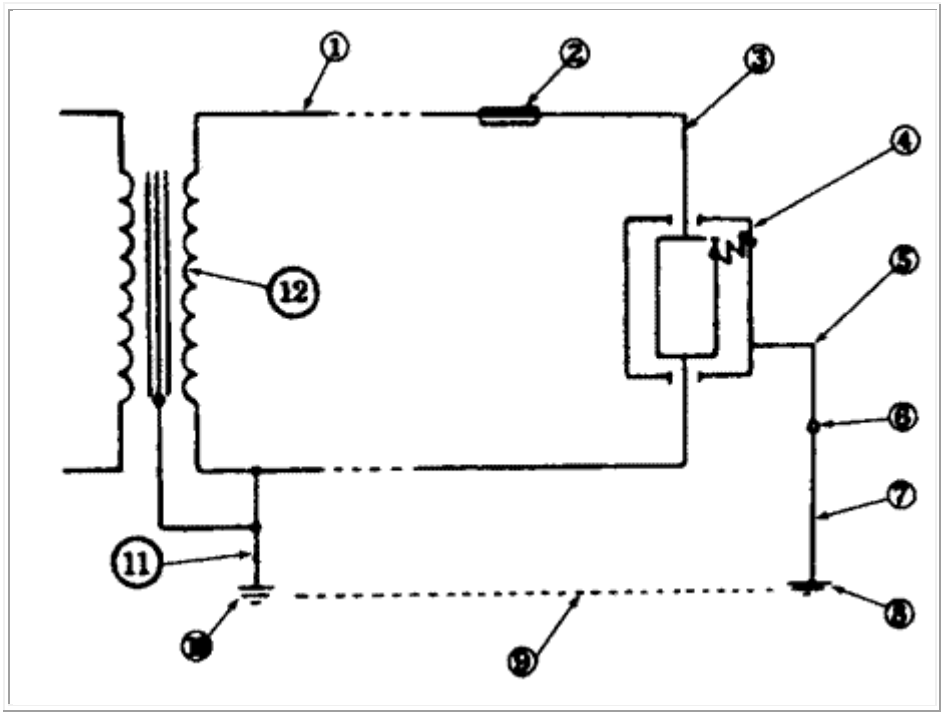


Fig.6 The earth fault loop

l. - the phase conductor from the transformer to the installation

2-the protective device(s) in the installation

3-the installation phase conductors from the intake position to the fault

4. - the fault itself (usually assumed to have zero impedance)

5. - the protective conductor system

6. - the main earthing terminal

7. - the earthing conductor

8. - the installation earth electrode

9. - the general mass of earth

10. - the Supply Company's earth electrode

11. - the Supply Company's earthing conductor

12-the secondary winding of the supply transformer

- For a TN-S system (where the Electricity Supply Company provides an earth terminal), items 8 to 10 are replaced by the PE conductor, which usually takes the form of the armouring (and sheath if there is one) of the underground supply cable.
- For a TN-C-S system (protective multiple earthing) items 8 to 11 are replaced by the combined neutral and earth conductor.
- For a TN-C system (earthed concentric wiring), items 5 to 11 are replaced by the combined neutral and earth wiring of both the installation and of the supply.

It is readily apparent that the impedance of the loop will probably be a good deal higher for the TT system, where the loop includes the resistance of two earth electrodes as well as an earth path, than for the other methods where the complete loop consists of metallic conductors.

Earthing system components (**6,7 and 8**)

Earthing system has three main componens

- **Earthing conductors**
- **Earthing electrods**
- **Inspection points (earthing well)**

1- Earthing conductors

The earthing conductor is commonly called the earthing lead. It joins the installation earthing terminal to the earth electrode or to the earth terminal provided by the Electricity Supply Company. It is a vital link in the protective system, so care must be taken to see that its integrity will be preserved at all times.

2- Earth electrodes

The principle of earthing is to consider the general mass of earth as a reference (zero) potential. Thus, everything connected directly to it will be at this zero potential. The purpose of the earth electrode is to connect to the general mass of earth ,(see Fig.7).

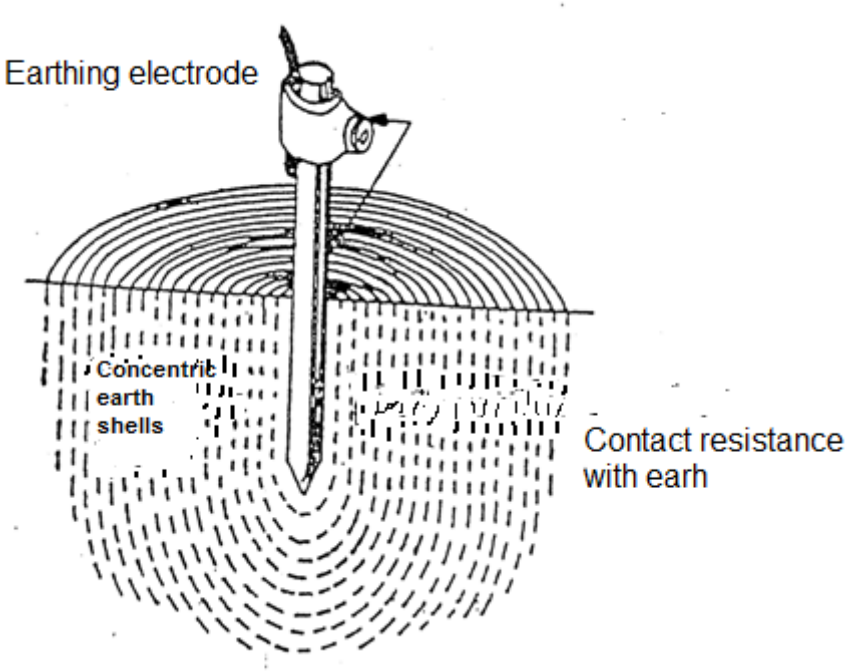


Fig.7 **Earth electrode**

Calculation of earthing resistance for one electrode driven at the earth

Equation used to calculate earthing resistance is:

$$R = (\rho / 2\pi l)[\ln (8l /d) -1] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where

ρ = earth resistivity in ohm.m

l = length of the electrode (m)

d= diameter of the electrod in (m)

Example 1 : calculate the earthing resistance of an earthing electrode of length 3m and its diameter is 2 cm driven in an earth of 60 Ω.m resistivity.

Solution:

$$R_I = (\rho / 2\pi \ l)[\ln (8l /d) -1] = (60 / 2\pi x3)[\ln (8x3/ 0.02)-1] = 19.4 \ \Omega$$

This is very large value. To reduce this resistance we can put another rode (electrode) at distance D in parallel with the first rode. Hence the total earthing resistance R_{II} will be:

$$R_{II} = ((1+ \alpha) / 2) \ R_I$$

$$\alpha = (\rho / 2\pi \ D \ R_I) \qquad (2)$$

Example 2: For example 1 above calculate the erthing resistancse when two similar electrod are put in parallel.

Solution:

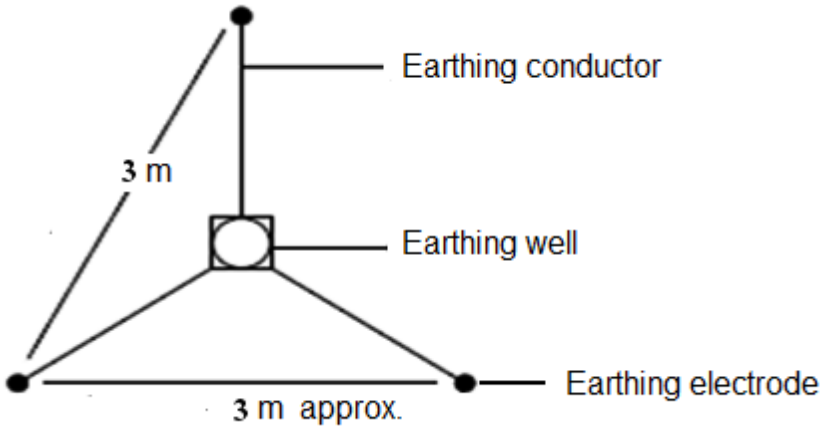
From example 1 R_I=19.4 Ω

$$\alpha = (\rho / 2\pi \ D \ R_I) = (60/ 2x3.14x3x19.4) = 0.16$$

$$R_{II} = \{(1+ 0.16) /2 \ \} (19.4) = 11.25 \ \Omega$$

For standard building, it is found that the best earthing system is to use thee rodes connected in triangular form as shown in Fig.8, in this case the earthing resistance will be reduce to $R_{III}= R_I/3$.

Fig.8



For any number of rods in parallel, we can calculate the earhing resistance from the following equation and table:

$$R_{eq} = [\ RI / \text{No. of rods.}] \times F \qquad (9\text{-}4)$$

Where F is a multiplying factor that can be taken from the following table-1.The resistivity (ρ) in . (Ω . m) for various types of soils are given table-2.

Table-1

F	No.of rods
1.16	2
1.29	3
1.36	4
1.68	8
1.8	12
1.92	16
2.0	20

Table-2

. (m. Ω) ρ المقاومية	Type of soil نوع التربة
30 – 5	مستنقعات وترب مغمورة بالماء
100 – 20	تربة طينية
500 – 50	طين – رمل
3000 – 200	رمل سليكوني
3000 – 1500	أرض صخرية

3- Inspection points (Earthing well)

For protection of the earthing rod and earthing conductors and also for maintenance and inspection purposes an earth well is constructed as shown in Fig.9. Earthing conductors, as well as protective and bonding conductors, must be protected against corrosion. Probably the most common type of corrosion is electrolytic, which is an electro-chemical effect between two different metals when a current passes between them whilst they are in contact with each other and with a weak acid. The acid is likely to be any moisture which has become contaminated with chemicals carried in the air or in the ground.

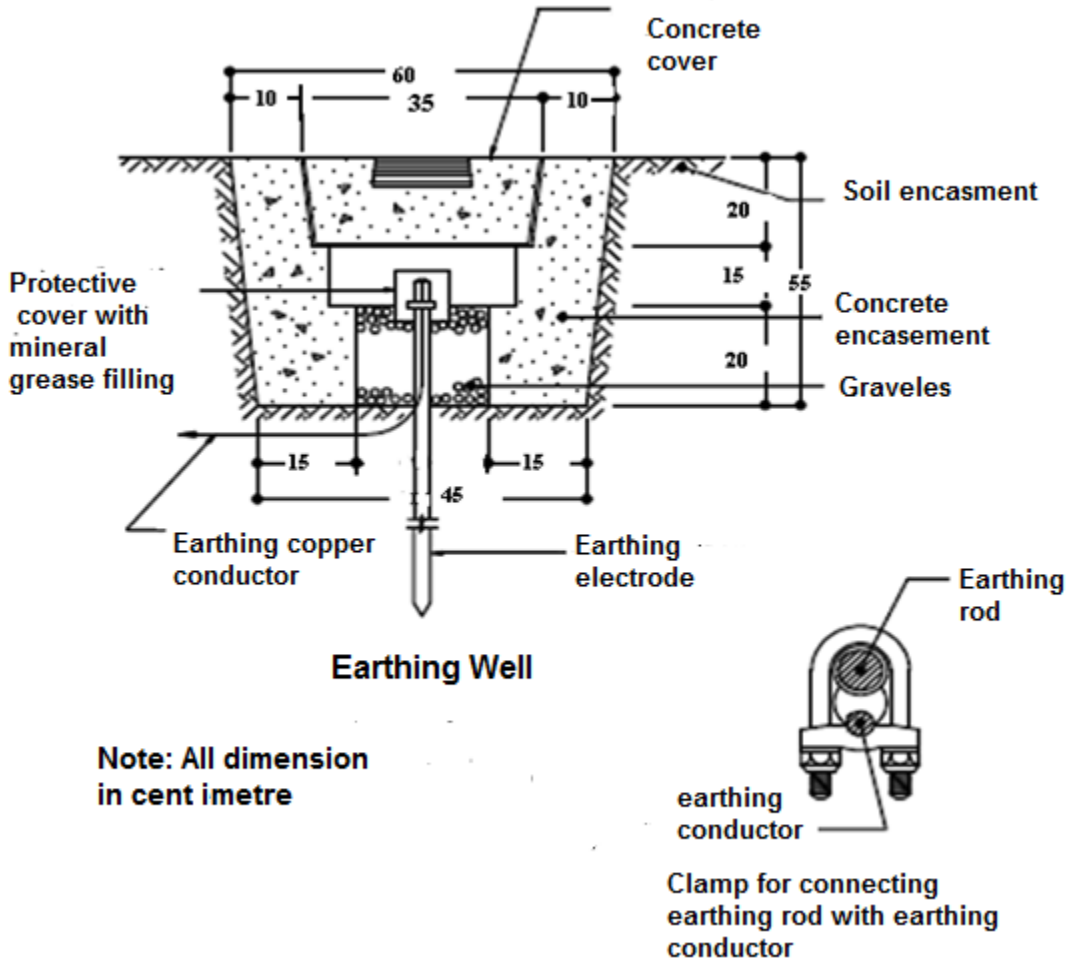


Fig.9 Earthing well

- A main earth terminal or bar must be provided for each installation to collect and connect together all protective and bonding conductors. It must be possible to disconnect the earthing conductor from this terminal for test purposes, but only by the use of a tool. This requirement is intended to prevent unauthorised or unknowing removal of protection.

- Where the final connection to the earth electrode or earthing terminal is made there must be a clear and permanent label **Safety Electrical Connection - Do not remove** (see {Fig.10}).

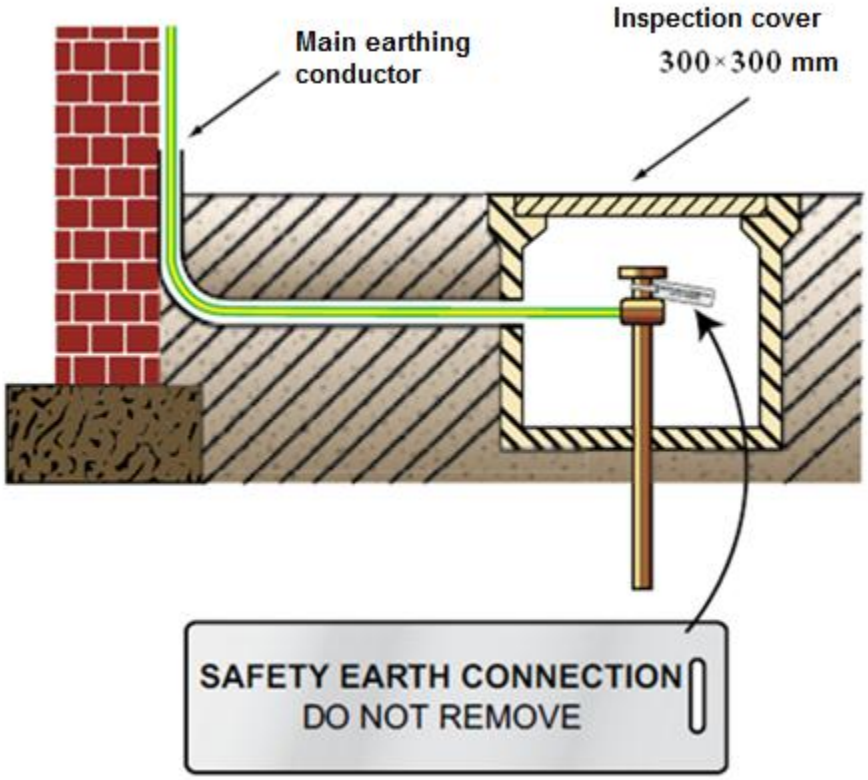


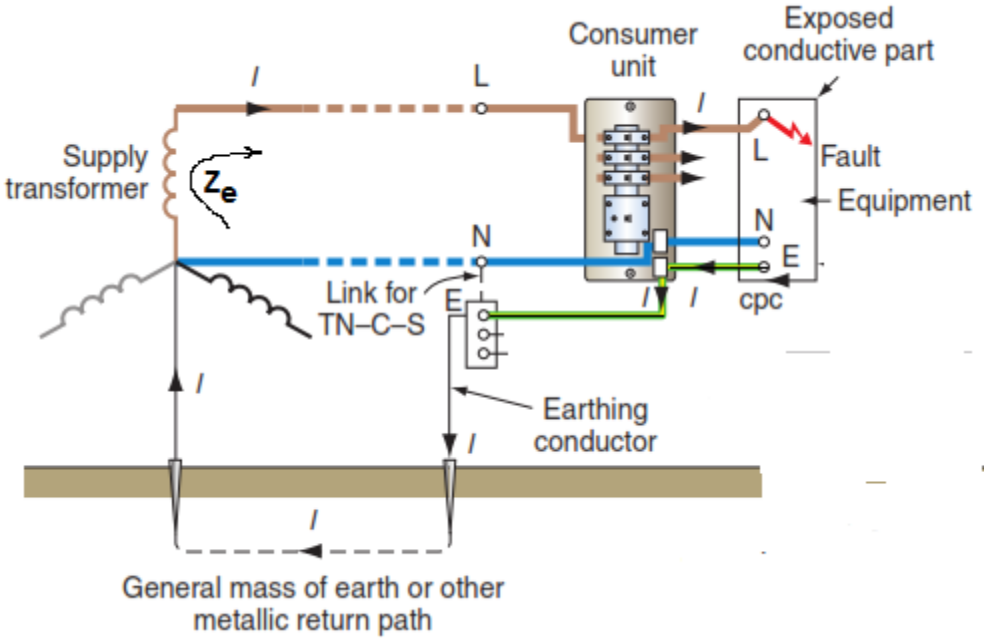
Fig.10

- With the increasing use of underground supplies and of protective multiple earthing (PME) it is becoming more common for the consumer to be provided with an earth terminal rather than having to make contact with earth using an earth electrode.

What is protective multiple earthing?

- If a continuous metallic earth conductor exists from the star point of the supply transformer to the earthing terminal of the installation, it will run throughout in parallel with the installation neutral, which will be at the same potential. It therefore seems logical that one of these conductors should be removed, with that remaining acting as a combined protective and neutral conductor (PEN). When this is done, we have a TN-C-S installation .***The combined earth and neutral system will apply only to the supply, and not to the installation.***
- PME can be installed by the Electricity Supply Company ***only*** after the supply system and the installations it feeds must have complied with certain requirements.
- The great virtue of the PME system is that neutral is bonded to earth so that a phase to earth fault is automatically a phase to neutral fault. The earth-fault loop impedance will then be low, resulting in a high value of fault current which will operate the protective device quickly. It must be stressed that the neutral and earth conductors are kept quite separate within the installation: the main earthing terminal is bonded to the incoming combined earth and neutral conductor by the Electricity Supply Company. The difficulty of ensuring that bonding requirements are met on construction sites means that PME supplies must not be used. Electricity Supply Regulations forbid the use of PME supplies to feed caravans and caravan sites.

Protective earthing, protective conductor and automatic disconnection in case of a fault (Fault protection)



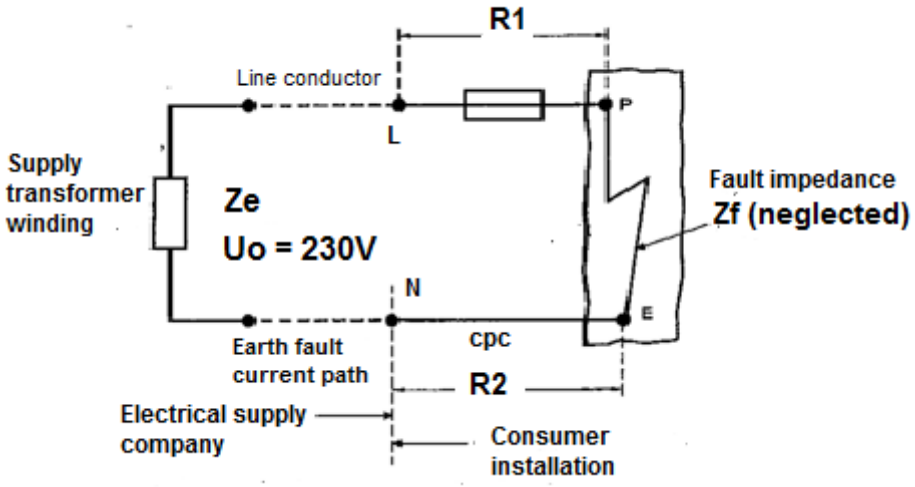


Fig.1 Earth fault loop path.

Figure 1 shows the earth fault system which provides Fault protection. The low impedance path for fault currents, the earth *fault loop path*, comprises that part of the system external to the installation, i.e. the impedance of the supply transformer, distributor and service cables Ze , and the resistance of the line conductor R_1 and circuit protective conductor (cpc) R_2 of the circuit .

The total value of loop impedance *Zs* , of the circuit concerned is therefore the sum of these values:

$$Z_s = Z_e + (R_1 + R_2)\Omega$$

External loop impedance Z_e

The designer obviously has some measure of control over the values of R_1 and R_2 , but the value of *Ze* can be selected from the following table:

Table 15-1

TT system	21 Ω
TN-S system	0.8 Ω
TN-C-S system	0.35 Ω

Example1

A single-phase circuit is run in single-core 70ºC pvc-insulated and sheathed cables clipped direct and not bunched with cables of other circuits. Protection against indirect contact is provided by a device of a type listed earlier in lecture 12. If the conductors are copper, the cross-sectional area of the live conductors is 4 mm^2 and that of the protective conductor is 2.5 mm^2, l is 45 m and the supply being PME or TN-c-s system, what is the earth fault loop impedance?

Answer

The relevant table is Table (3-23) so that the value of (R1+R2) / km in ohms /km is obtained from Column 2 in Table 3-23. It is found to be 11.04 ohms / km.

From table 15-1 , for TN-C-S system , Ze = 0.35 ,hence

$$Z_s = 0.35 + \left(\frac{45 \times 11.04}{1000}\right)\text{ohm} = 0.845\text{ohm}$$

Example 2: A 10 mm^2 PVC sheathed PVC insulated copper cable is short-circuited when connected to a 400V supply. The impedance of the short-circuit path is 0.1Ω.Calculate the maximum permissible disconnection time and show that a 50 A Type B MCB depicted in Fig. 2 will meet this requirement.
Solution:

$$I = \frac{V}{Z}$$

$$I = \frac{400}{0.1} = 4000A$$

$$\therefore Fault\ current = 4000A$$

For PVC sheathed copper cables, a value for k of 115. So,

$$t = \frac{k^2 S^2}{I^2}$$

$$t = \frac{115^2 x 10^2}{4000^2} = 82.66 \text{ x } 10^{-3}\ s$$

The maximum time that a 4000 A fault current can be applied to this 10 mm2 cable without dangerously raising the conductor temperature is 82.66 ms. Therefore, the protective device must disconnect the supply to the cable in less than 82.66 ms under short-circuit conditions.

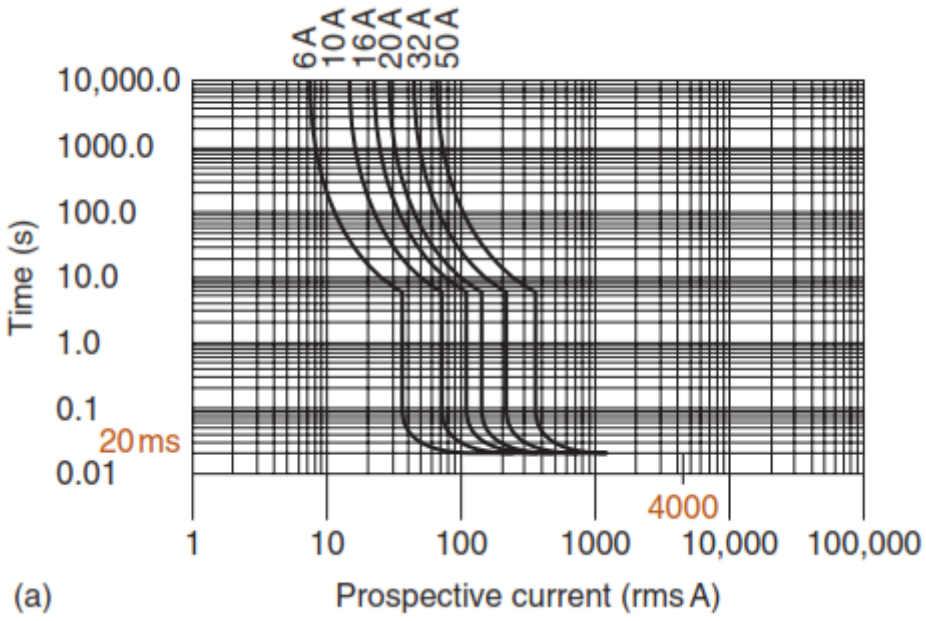


Fig. 2 Time/current characteristics of a Type B MCB.

Figure 2 shows the time/current characteristics for a Type B MCB. This graph shows that a fault current of 4000 A will trip the protective device in 20 ms. Since this is quicker than 82.66 ms, the 50 A Type B MCB is suitable and will clear the fault current before the temperature of the cable is raised to a dangerous level.

Size of the earthing conductors for equipment

The following table2 gives the minimum size of the earthing conductors for electrical equipment (luminaires ,motors ,socket outlets etc.....).

Table-2

Cross sectional area of the phase conductor supplying equipment (mm^2) S	**Minimum cross section of the earthing conductor required S_E (mm^2)**
$S \leq 16$	S
$16 < S \leq 35$	16
$S > 35$	S/2

The principle of the residual current device RCD

The RCD is a circuit breaker which continuously compares the current in the phase with that in the neutral. The difference between the two (the residual current) will he flowing to earth, because it has left the supply through the phase and has not returned in the neutral (see {Fig.3}). There will always be some residual current in the insulation resistance

and capacitance to earth, but in a healthy circuit such current will be low, seldom exceeding 2 mA.

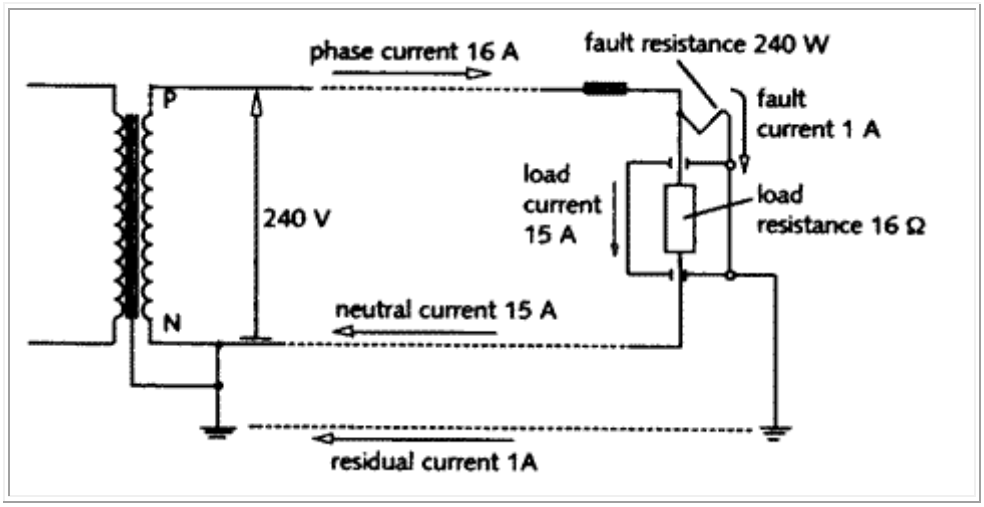


Fig.3 The meaning of the term residual current

The purpose of the residual current device is to monitor the residual current and to switch off the circuit quickly if it rises to a preset level. The arrangement of an RCD is shown in simplified form in {Fig.4}. The main contacts are closed against the pressure of a spring, which provides the energy to open them when the device trips. Phase and neutral currents pass through identical coils wound in opposing directions on a magnetic circuit, so that each coil will provide equal but opposing numbers of ampere turns when there is no residual current. The opposing ampere turns will cancel, and no magnetic flux will be set up in the magnetic circuit.

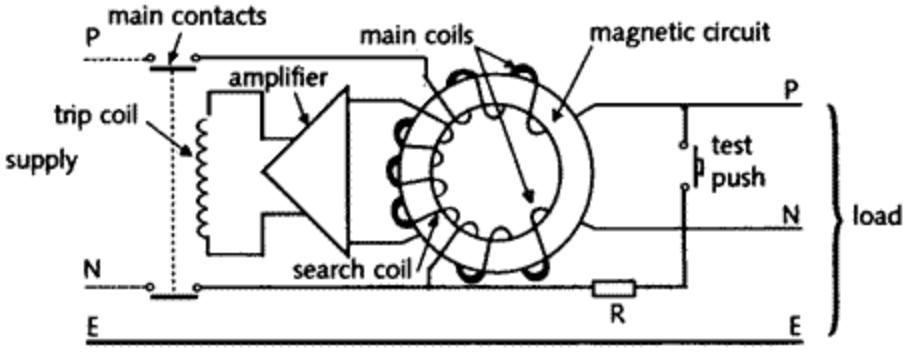


Fig.4

Effective discrimination of protective devices

In the event of a fault occurring on an electrical installation only the protective device nearest to the fault should operate,leaving other healthy circuits unaffected. A circuit designed in this way would be considered to have effective discrimination. Effective discrimination can be achieved by graded protection since the speed of operation of the protective device increases as the rating decreases. This can be seen in Fig1 .A fault current of 200 A will cause a 15A semi-enclosed fuse to operate in about0.1 seconds, a 30 A semi-enclosed fuse in about 0.4 seconds and a 60 A semi-enclosed fuse in about 5.0 seconds. If a circuit is arranged as shown in Fig.2 and a fault occurs on the appliance, effective discrimination will be achieved because the 15 A fuse will operate more quickly than the other protective devices if they were all semi-enclosed type fuses with the characteristics shown in Fig. 1 .Security of supply, and therefore effective discrimination, is an important consideration for an electrical designer and is also a requirement of the Regulations.

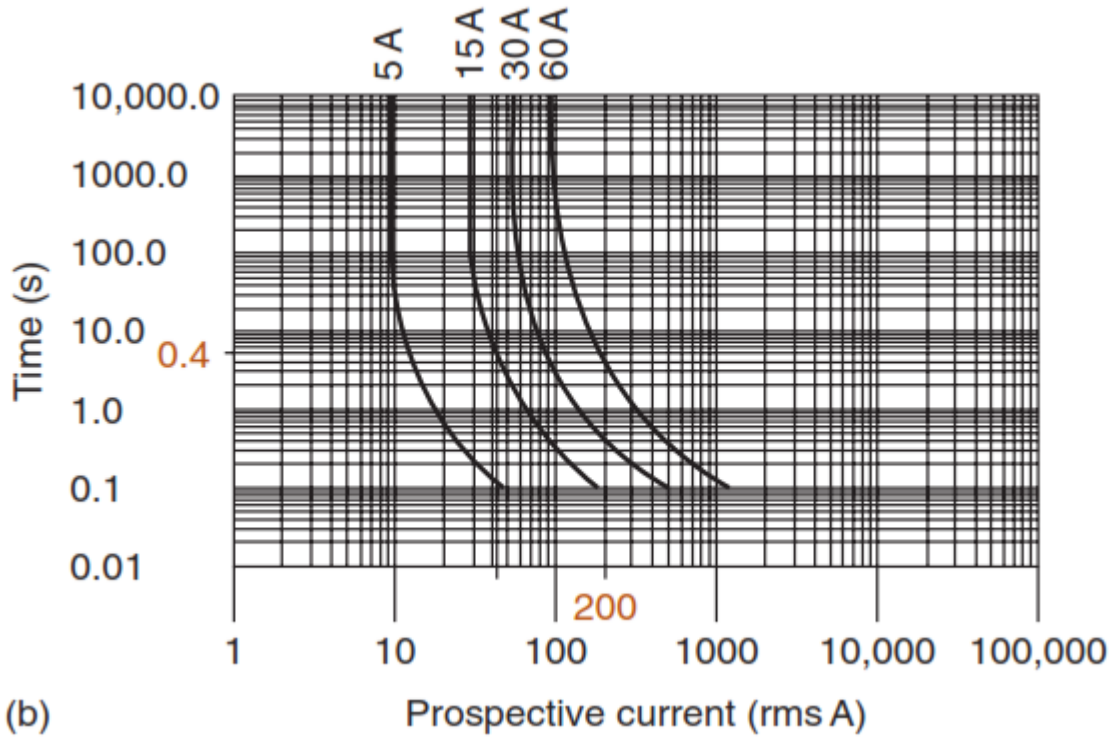


FIGURE 1 Time/current characteristics of semi-enclosed fuse to BS 3036.

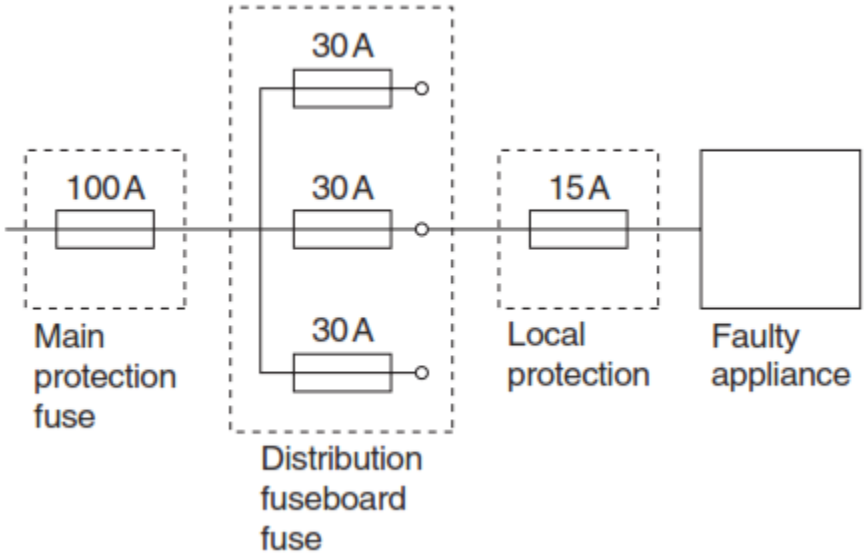


FIGURE 2 Effective discrimination achieved by graded protection.

The basic functions of LV switchgear

The role of switchgear is:

- ***Electrical protection***
- ***Safe isolation from live parts***
- ***Local or remote switching***

Electrical protection at low voltage is (apart from fuses) normally incorporated in circuit-breakers, in the form of thermal-magnetic devices and/or residual-current operated tripping devices .
In addition to those functions shown in Figure 1, other functions, namely:

- Over-voltage protection
- Under-voltage protection

are provided by specific devices, relays associated with contactors, remotely controlled circuit-breakers, and with combined circuit-breaker/isolators… and so on)
The aim is to avoid or to limit the destructive or dangerous consequences of excessive (short-circuit) currents, or those due to overloading and insulation failure, and to separate the defective circuit from the rest of the installation.
A distinction is made between the protections of:

- The elements of the installation (cables, wires, switchgear…)
- Persons and animals
- Equipment and appliances supplied from the installation

Types of switching devices

Device	Application	Comments
Isolator or disconnector	Performs the function of isolation	Not designed to be operated on load. Isolation can also be achieved by the removal of fuses, pulling plugs, etc.
Functional switch	Any situation where a load needs to be frequently operated, i.e. light switches, switches on socket outlets, etc.	A functional switch could be used as a means of isolation, i.e. a one-way light switch provides isolation for lamp replacement provided the switch is under the control of the person changing the lamp.
Switch-fuse	At the origin of an installation or controlling sub-mains or final circuits	These can perform the function of isolation while housing the circuit protective devices.
Fuse-switch	As for switch-fuse	Mainly used for higher current ratings and have their fuses as part of the moving switch blades.
Switch disconnector	Main switch on consumer units and distribution fuse boards	These are ON LOAD devices but can still perform the function of isolation.

The protection of circuits

- Against overload; a condition of excessive current being drawn from a healthy (unfaulted) installation
- Against short-circuit currents due to complete failure of insulation between conductors of different phases or (in TN systems) between a phase and neutral (or PE) conductor Protection in these cases is provided either by fuses or circuit-breaker, in the distribution board at the origin of the final circuit (i.e. the circuit to which the load is connected.

The protection of persons

- Against insulation failures. According to the system of earthing for the installation (TN, TT or IT) the protection will be provided by fuses or circuit-breakers, residual current devices, and/or permanent monitoring of the insulation resistance of the installation to earth.

The protection of electric motors

- Against overheating, due, for example, to long term overloading, stalled rotor

single-phasing, etc. Thermal relays, specially designed to match the particular characteristics of motors are used. Such relays may, if required, also protect the motor-circuit cable against overload. Short-circuit protection is provided either by type aM fuses or by a circuit-breaker from which the thermal (overload) protective element has been removed, or otherwise made inoperative.

2. Elementary switching devices

Disconnector (or isolator) (see **Fig. 3**)

This switch is a manually-operated, lockable, two-position device (open/closed) which provides safe isolation of a circuit when locked in the open position. Its characteristics are defined in IEC 60947-3. A disconnector is not designed to make or to break current and no rated values for these functions are given in standards. It must, however, be capable of withstanding the passage of short-circuit currents and is assigned a rated short-time withstand capability, generally for 1 second, unless otherwise agreed between user and manufacturer. This capability is normally more than adequate for longer periods of (lower-valued) operational overcurrents, such as those of motor-starting. Standardized mechanical-endurance, overvoltage, and leakage-current tests, must also be satisfied.

Fig. 3 : Symbol for a disconnector (or isolator)

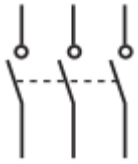
Load-breaking switch (see **Fig. 4**)

This control switch is generally operated manually (but is sometimes provided with electrical tripping for operator convenience) and is a non-automatic two-position device (open/closed).
It is used to close and open loaded circuits under normal unfaulted circuit conditions It does not consequently, provide any protection for the circuit it controls.
The utilization categories referred to in **Figure 4** do not apply to an equipment normally used to start, accelerate and/or stop individual motors.

Example
A 100 A load-break switch of category AC-23 (inductive load) must be able:

- To make a current of 10 I_n (= 1,000 A) at a power factor of 0.35 lagging
- To break a current of 8 I_n (= 800 A) at a power factor of 0.45 lagging
- To withstand short duration short-circuit currents when closed

Fig. 4 : Symbol for a load-break switch



Remote control switch (see **Fig. 5**)

This device is extensively used in the control of lighting circuits where the depression of a pushbutton (at a remote control position) will open an already-closed switch or close an opened switch in a bistable sequence.
Typical applications are:

- Two-way switching on stairways of large buildings
- Stage-lighting schemes
- Factory illumination, etc.

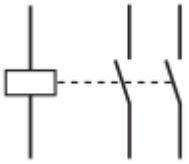


Fig.5

It is also called teleruture switch.

Fig. 5 : Symbol for a bistable remote control switch

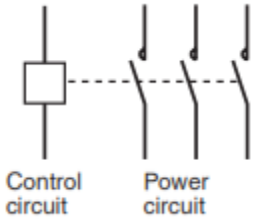
Contactor (see **Fig. 6**)

The contactor is a solenoid-operated switching device which is generally held closed by (a reduced) current through the closing solenoid (although various mechanically-latched types exist for specific duties). Contactors are designed to carry out numerous close/open cycles and are commonly controlled remotely by on-off pushbuttons. The large number of repetitive operating cycles is standardized in table VIII of IEC 60947-4-1 by:

- The operating duration: 8 hours; uninterrupted; intermittent; temporary of 3, 10, 30, 60 and 90 minutes
- Utilization category: for example, a contactor of category AC3 can be used for the starting and stopping of a cage motor
- The start-stop cycles (1 to 1,200 cyles per hour)
- Mechanical endurance (number of off-load manœuvres)
- Electrical endurance (number of on-load manœuvres)
- A rated current making and breaking performance according to the category of utilization concerned

Example:
A 150 A contactor of category AC3 must have a minimum current-breaking capability of 8 I_n (= 1,200 A) and a minimum current-making rating of 10 I_n (= 1,500 A) at a power factor (lagging) of 0.35.

Fig. 6 : Symbol for a contactor



3. Protection of people

Where utility power supply systems and consumers' installations form a TT earthed system, the governing standards impose the use of RCDs to ensure the protection of persons

On TT earthed systems, the protection of persons is ensured by the following measures:

- Protection against indirect contact hazards by RCDs (see **Fig. 7**) of medium sensitivity (300 mA) at the origin of the installation (incorporated in the incoming supply circuit-breaker or, on the incoming feed to the distribution board). This measure is associated with a consumer installed earth electrode to which must be connected the protective earth conductor (PE) from the exposed conductive parts of all class I insulated appliances and equipment, as well as those from the earthing pins of all socket outlets.
- When the CB at the origin of an installation has no RCD protection, the protection of persons shall be ensured by class II level of insulation on all circuits upstream of the first RCDs. In the case where the distribution board is metallic, care shall be taken that all live parts are double insulated (supplementary clearances or insulation, use of covers, etc.) and wiring reliably fixed.
- Obligatory protection by 30 mA sensitive RCDs of socket outlet circuits, and circuits feeding bathroom, laundry rooms, and so on .

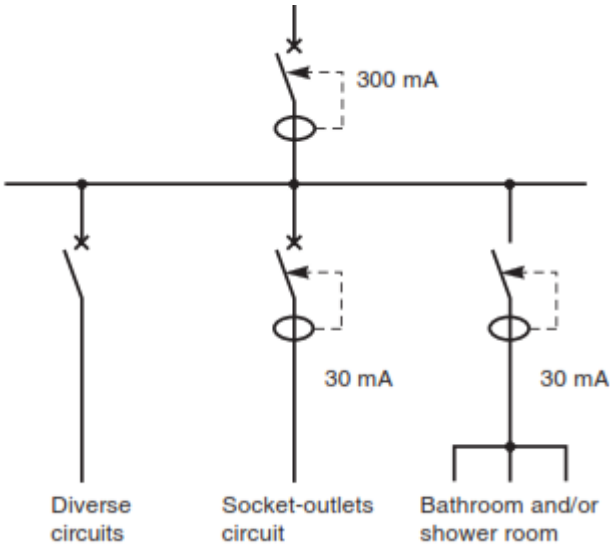
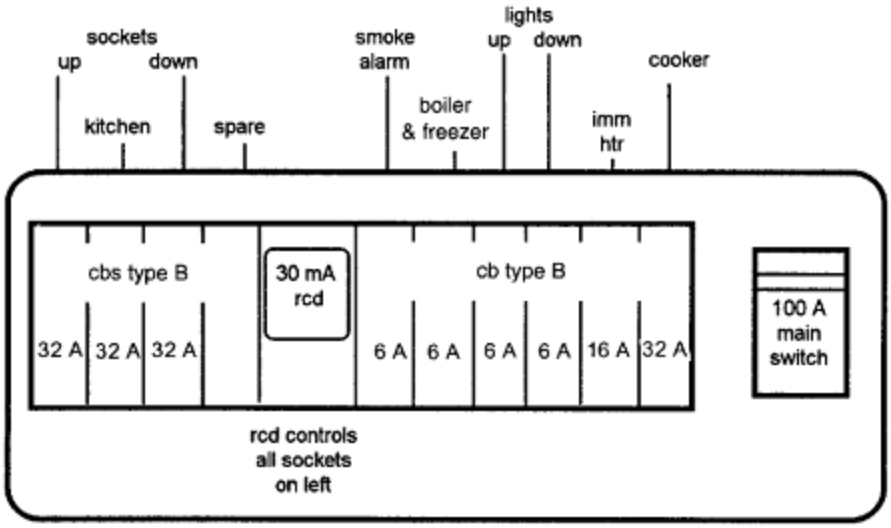


Fig. 7



476–01 amended A main switch for operation by unskilled persons, e.g. household or similar, shall interrupt both live conductors of a single phase supply.

Some domestic appliance information

Type of circuit single-phase 230 V 1 ph + N or 1 ph + N + PE	c. s. a. of the conductors	Maximum power	Protective device	
Fixed lighting	1.5 mm² (2.5 mm²)	2,300 W	Circuit-breaker Fuse	16 A 10 A
10/16 A	2.5 mm² (4 mm²)	4,600 W	Circuit-breaker Fuse	25 A 20 A
Individual-load circuits				
Water heater	2.5 mm² (4 mm²)	4,600 W	Circuit-breaker Fuse	25 A 20 A
Dish-washing machine	2.5 mm² (4 mm²)	4,600 W	Circuit-breaker Fuse	25 A 20 A
Clothes-washing machine	2.5 mm² (4 mm²)	4,600 W	Circuit-breaker Fuse	25 A 20 A
Cooker or hotplate (1)	6 mm² (10 mm²)	7,300 W	Circuit-breaker Fuse	40 A 32 A
Electric space heater	1.5 mm² (2.5 mm²)	2,300 W	Circuit-breaker Fuse	16 A 10 A

Distribution

- Electricity is supplied to a building by a supply authority. The supply is provided by a cable brought from outside into a suitable point in the building, which is referred to as the **main intake**, and from this the electricity has to be distributed to all outlets which use it. The incoming cable may be a 120 or 150 mm^2 pvc insulated cable and the current flowing along it must be divided between a number of smaller cables to be taken to the various final destinations throughout the building. This division is the function of the distributing system.

- The final distribution board or sub-circuits which serve the final outlets. Each final outlet takes a comparatively small current, and it would be impracticable to serve it with a large cable. The final sub-circuits are most commonly wired in 1.5 mm^2 , 2.5 mm^2 and 6 mm^2 cables. A typical scheme is shown diagrammatically in Fig 1.
- The cable from the main intake to a distribution board is known as a sub-main, and it must be rated to carry the maximum simultaneous current taken by all the final sub-circuits on that board.
- The fuses or circuit breakers in the distribution board protect the final sub-circuits, but the sub-main cable also needs protection against short circuits and overloads, and there must be a fuse or other protective device such as circuit breaker at the main intake.

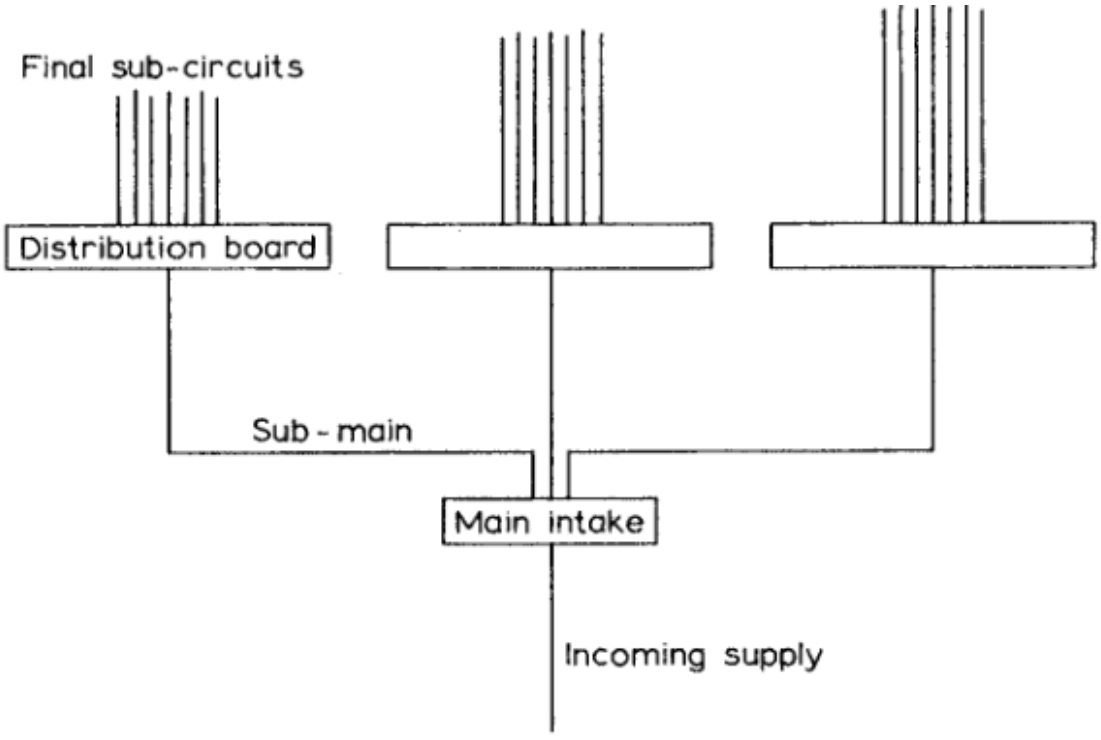


Fig.1

Standard Final distribution board

- Standard distribution boards usually have either 4, 6, 8,9, 12, 16, 18 , 24 , 36 or 42 circuit ways (see Fig.2). Both single and three phase boards are available, the latter having three circuit ways for each outgoing circuit. It is not necessary to utilize all the available circuitways on a board, and in fact it is very desirable to leave several spare ways on each board for future extensions. These are often required before a building is even finished, and are almost certain to be wanted during the life of an installation

Fig.2 Photograph of final distribution board (vertical, split busbar type)

House distribution

The number of circuits in a house is small enough to be accommodated on a single distribution board so that there is no need for sub-main distribution. The scheme thus becomes as shown diagrammatically in Fig.3. The incoming cable goes to a service cut out which is supplied, fixed and sealed by the Electricity Board. As a domestic supply does not normally exceed 100 A the whole can go through the meter and there is no occasion for the use of transformers. From the meter the cable goes straight to the distribution board.

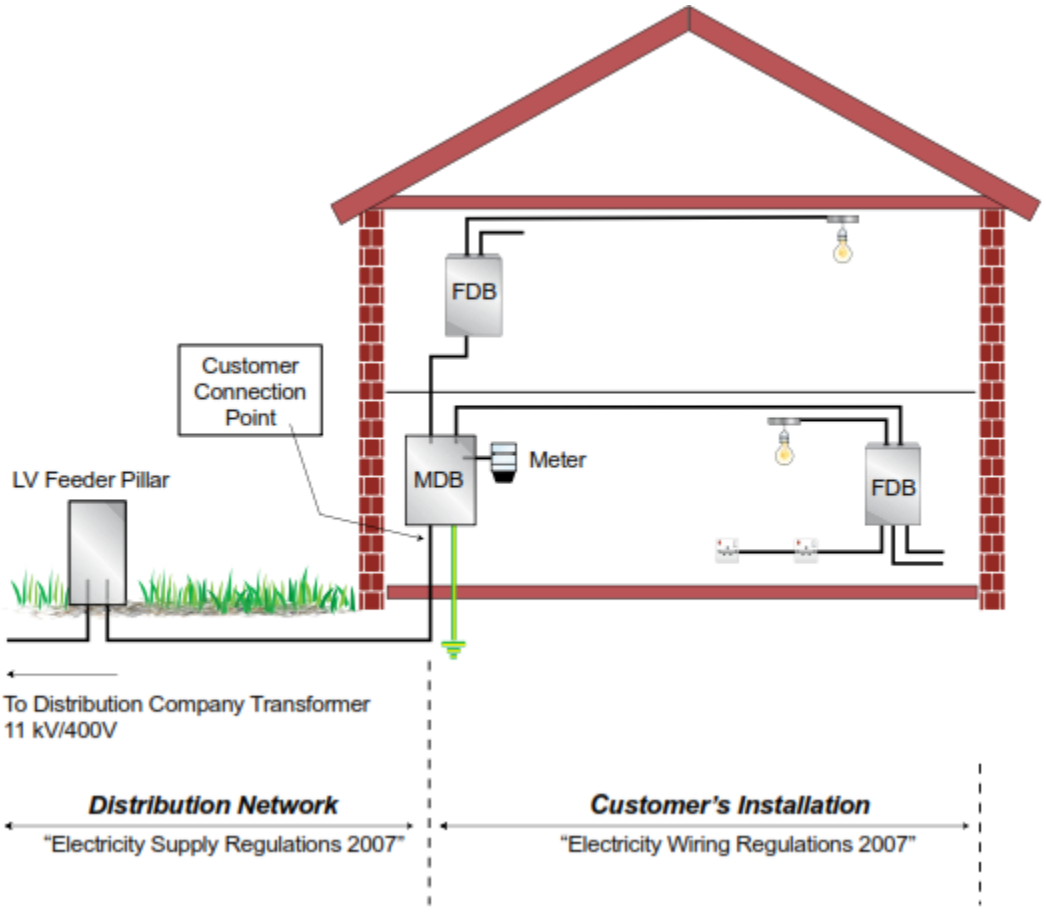


Fig. 3 Domestic service

The M.D.B contain main fuse which is a cartridge fuse, or main circuit breaker. It is installed in the meter board and sealed by the Jordanian Electric Power Company (JEPCO). This main fuse provides further backup protection in case of short circuits.

Watt-Hour Meter:

The Watt-hour meter used in Jordan for all types of installations is of the induction type designed to rotate an aluminium disk which in turn is mechanically coupled to drive a series of pointers or numerals from which the energy consumption is read. It measures the consumed energy over a certain period of time (e.g. one month or one quarter-3 months-) after which the meter is read by the supply authority and the charges calculated.

Energy is measured in joules (Watt-seconds), but for tariff purposes, the larger unit, the kilowatt-hour is used. Fig.4 shows the single phase induction watt-hour meter.

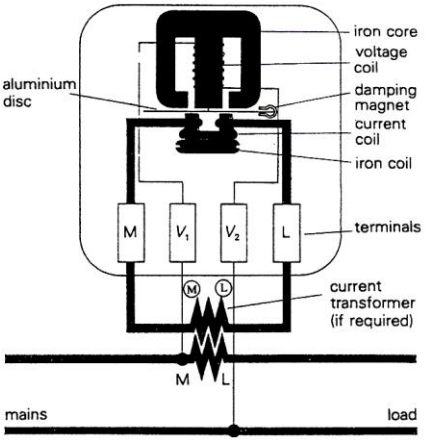


Fig. 4 Watt-hour meter

Main Circuit Breaker:

It is of the single-pole miniature type, it provides protection against overcurrent and short circuits, hence prevents damage of watt-hour meter. It is also installed by JEPCO with ratings depending on load (e.g. 30A, 60A).

Neutral Link:

It is a rectangular piece of drawn copper fitted onto the meter board and connected to the neutral conductor going out of the meter.

Final Distribution Boards (FDB):

The type used here is the M.C.B standard final distribution board; it consists of a prefabricated box of synthetic material of adequate strength, and is fitted on the wall. Fig.2 above.

Each F.D.B contains a phase busbar and a neutral busbar plus an earthing distribution point. The number of M.C.B's is equal to the number of circuits in a dwelling. A double-throw switch (isolator) is used to isolate and connect the D.B to the watt-hour meter. The F.D.B has a metallic cover to protect it from dust and intrusion. On the inside of the cover, there is a single line diagram showing all M.C.B's which are numbered for easy identification. All M.C.B's should be easy to replace.

Minimum number of socket-outlets and connection points in domestic services

Room	Minimum number of outlets for domestic premises
Kitchen:	
13 A switched socket-outlets (worktops)	Minimum 2 double, plus every 2 m of worktop
13 A switched socket-outlets (Appliances)	Minimum 1 single, plus as required for free standing Appliances (e.g. fridge)
Connection points (for washing machine, dryer etc)	Minimum 1, plus as required for number of items installed (flex outlets or socket-outlets)
Cooker control unit	1
Bedrooms	2 double, 1 single
Lounge or dining	3 double, 1 single
Hall or corridor	1 single
Bathrooms	only BS 3535 shaver socket (if required)

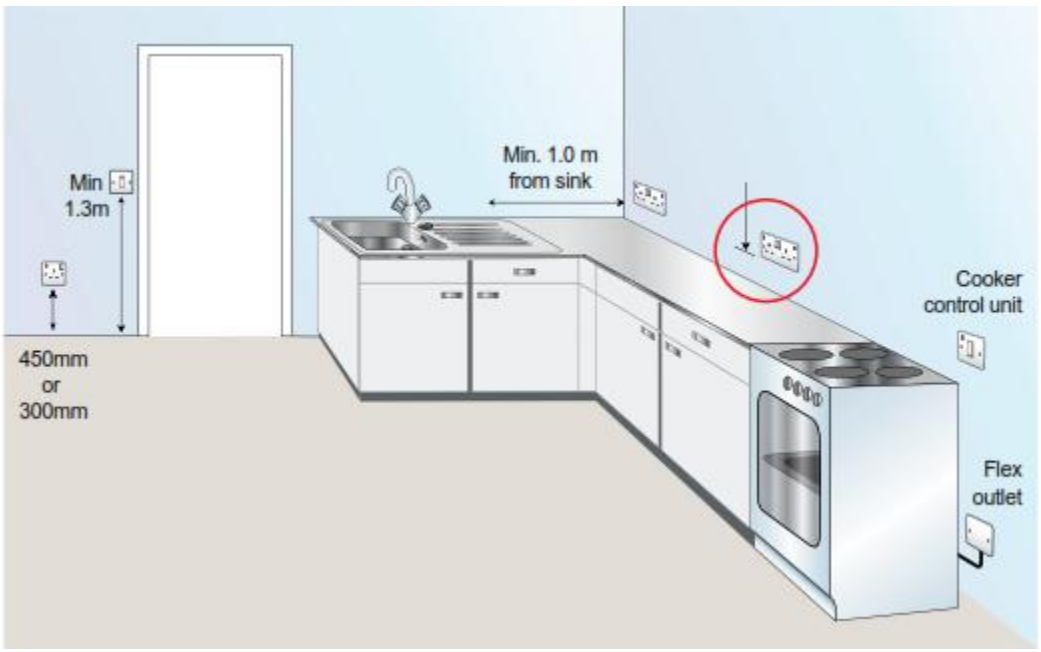
Note 1: in general, double socket-outlets should be used in preference to single socket-outlets wherever possible

Note 2: socket-outlets should be conveniently located to avoid the need for extension cables and adapters (which introduce risk of overheating and fire)

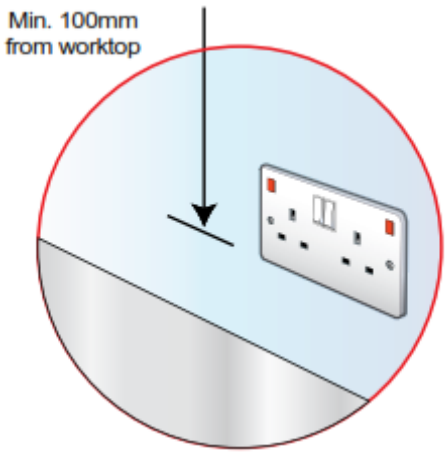
Note 3: 15A BS 546 socket-outlets are not permitted in domestic premises

Note 4: the maximum number of socket-outlets on a Circuit is not limited and is dependent on the load supplied and the wire size .

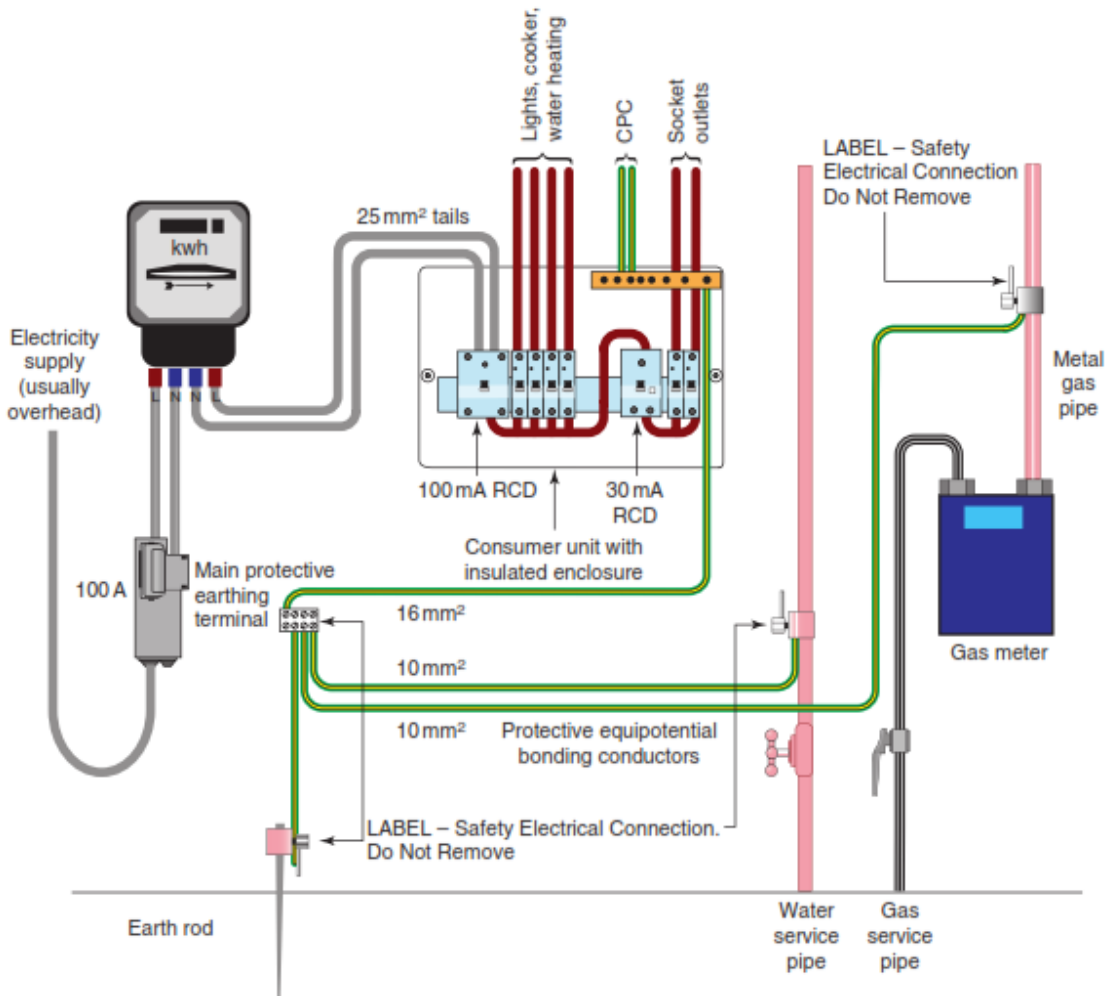
Mounting height for accessories and socket-outlets



Note: Mounting height may be varied for special circumstances such as access for disabled persons or children, etc.



Earthing Distribution: TT system at Domestic premises



TT – Earthing system at House

Flat distribution

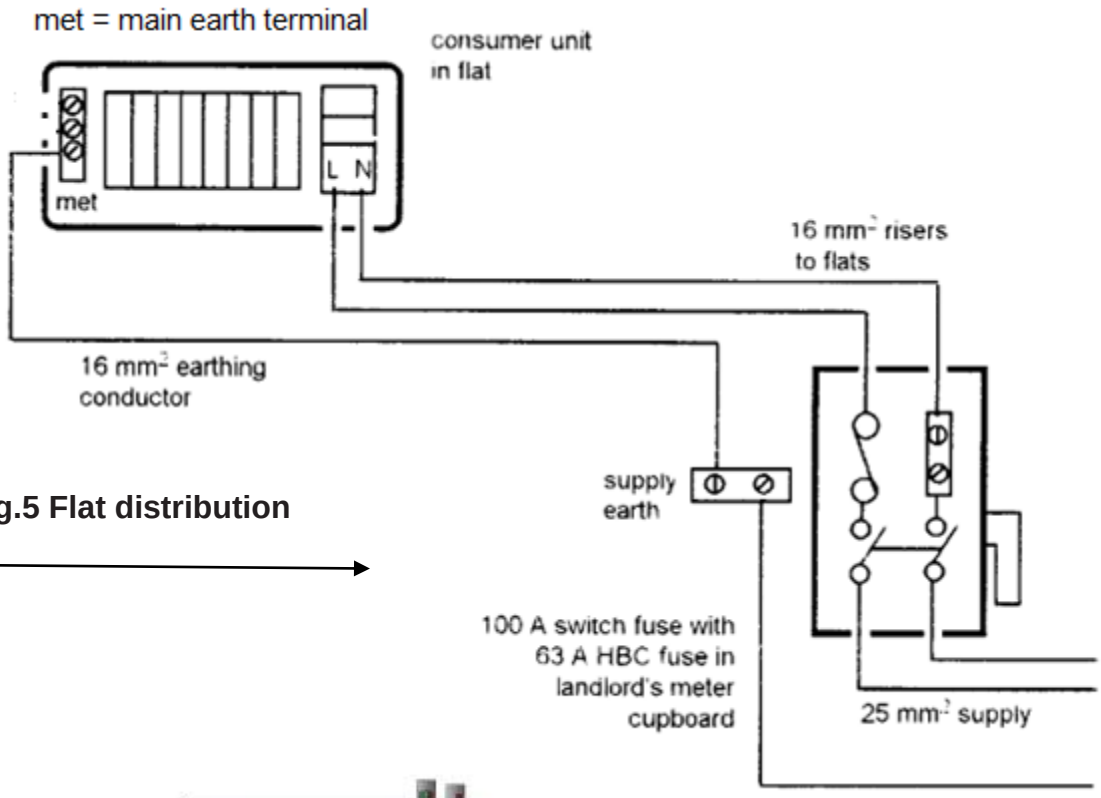


Fig.5 Flat distribution

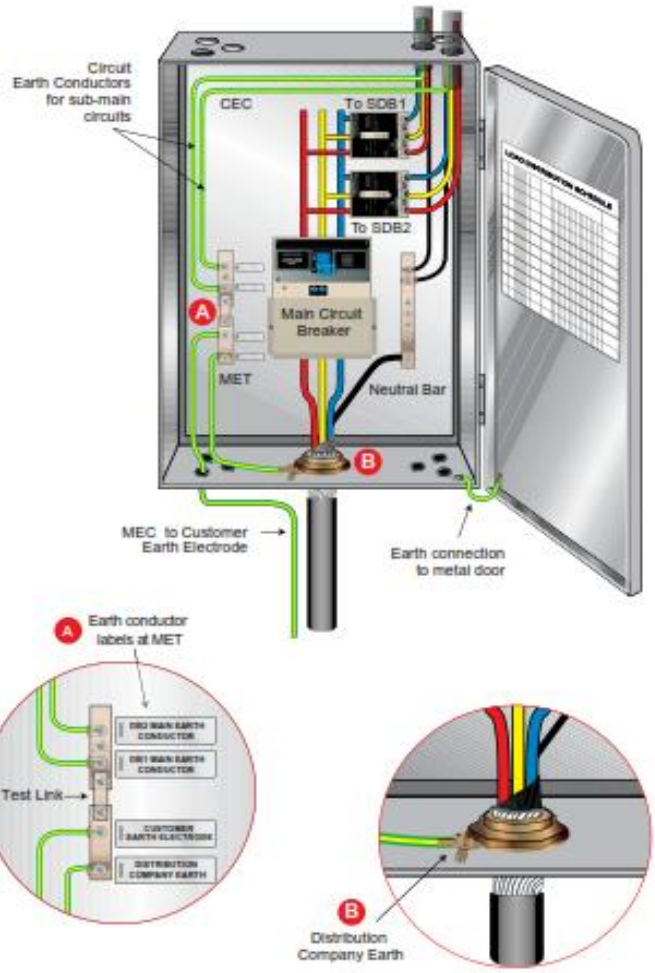


Fig.6 Main earth terminal (MET) at main distribution board (MDB)

Residential and similar premises

Electrical installations for residential premises need a high standard of safety and reliability
The power distribution utility connects the LV neutral point to its MV/LV distribution tranformer to earth.
All LV installations must be protected by RCDs.
All exposed conductive parts must be bonded together and connected to the earth.

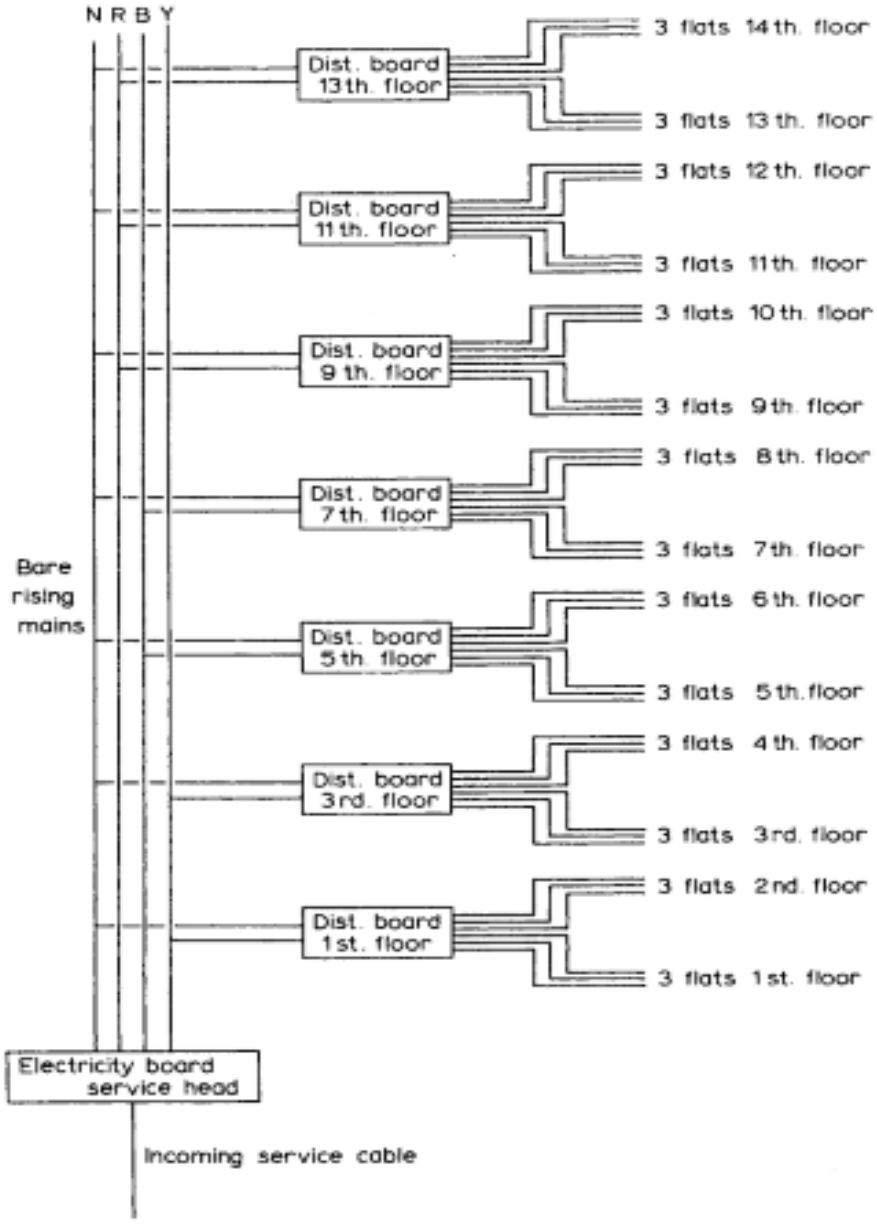


Fig.7 Residential building distribution

Office Building and Large premises distribution

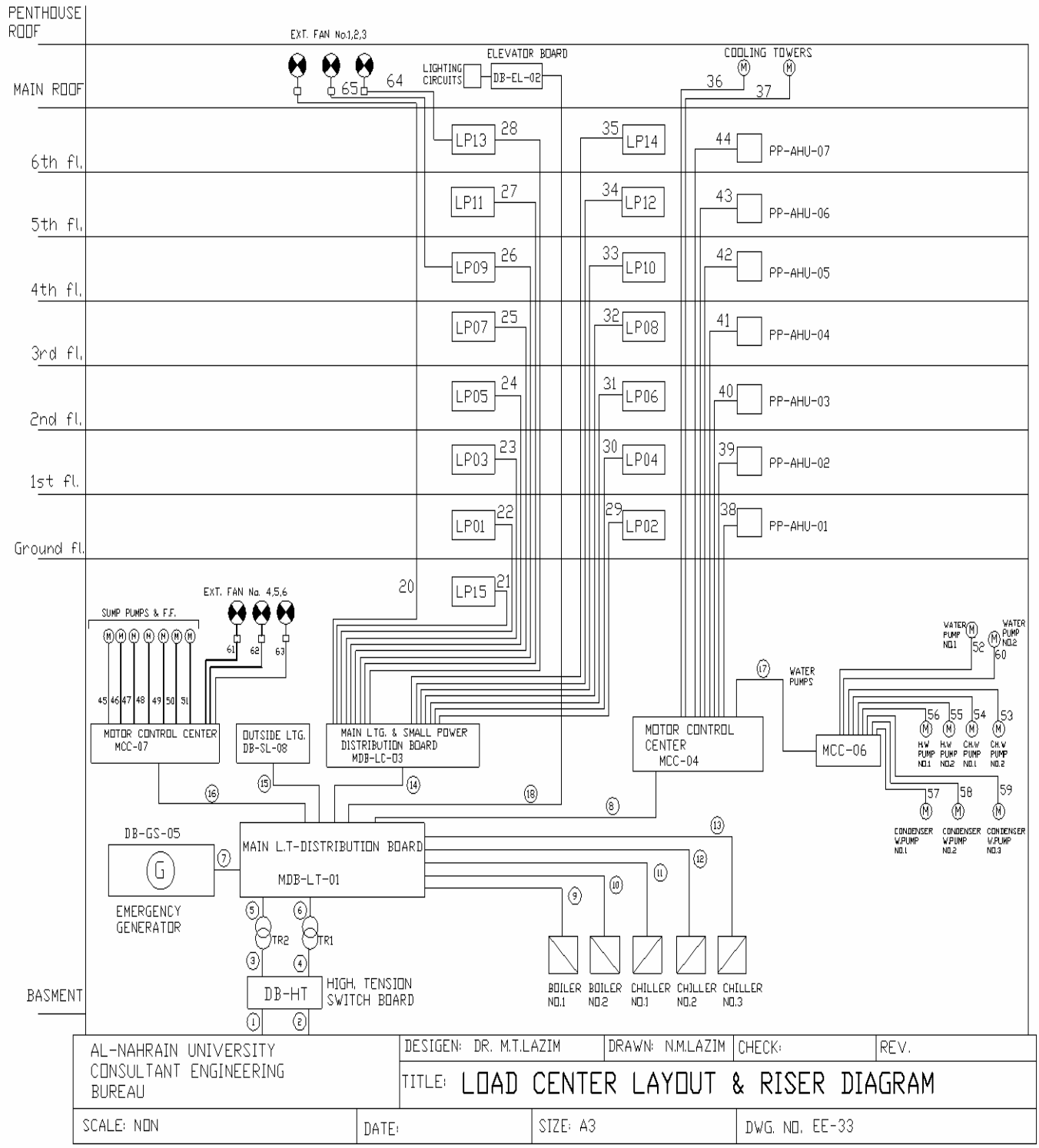
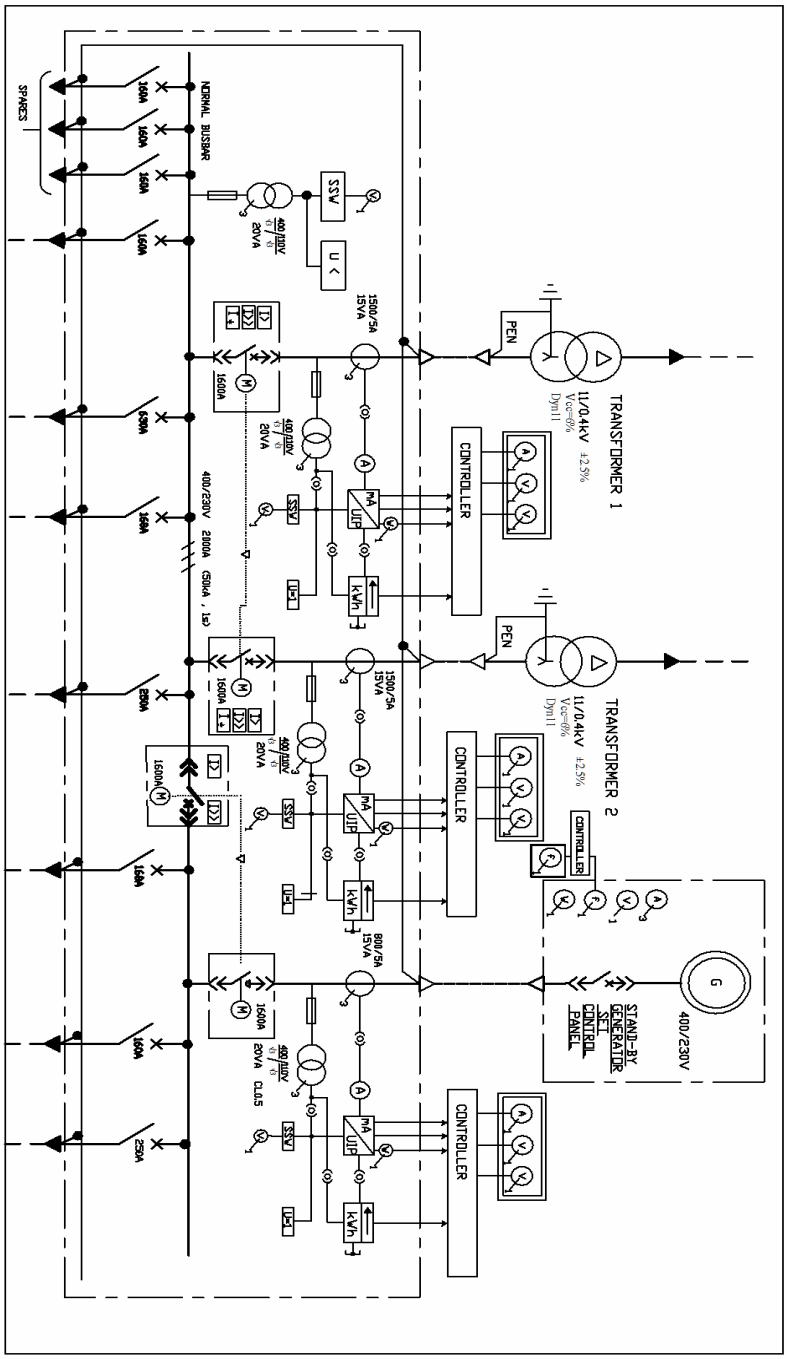


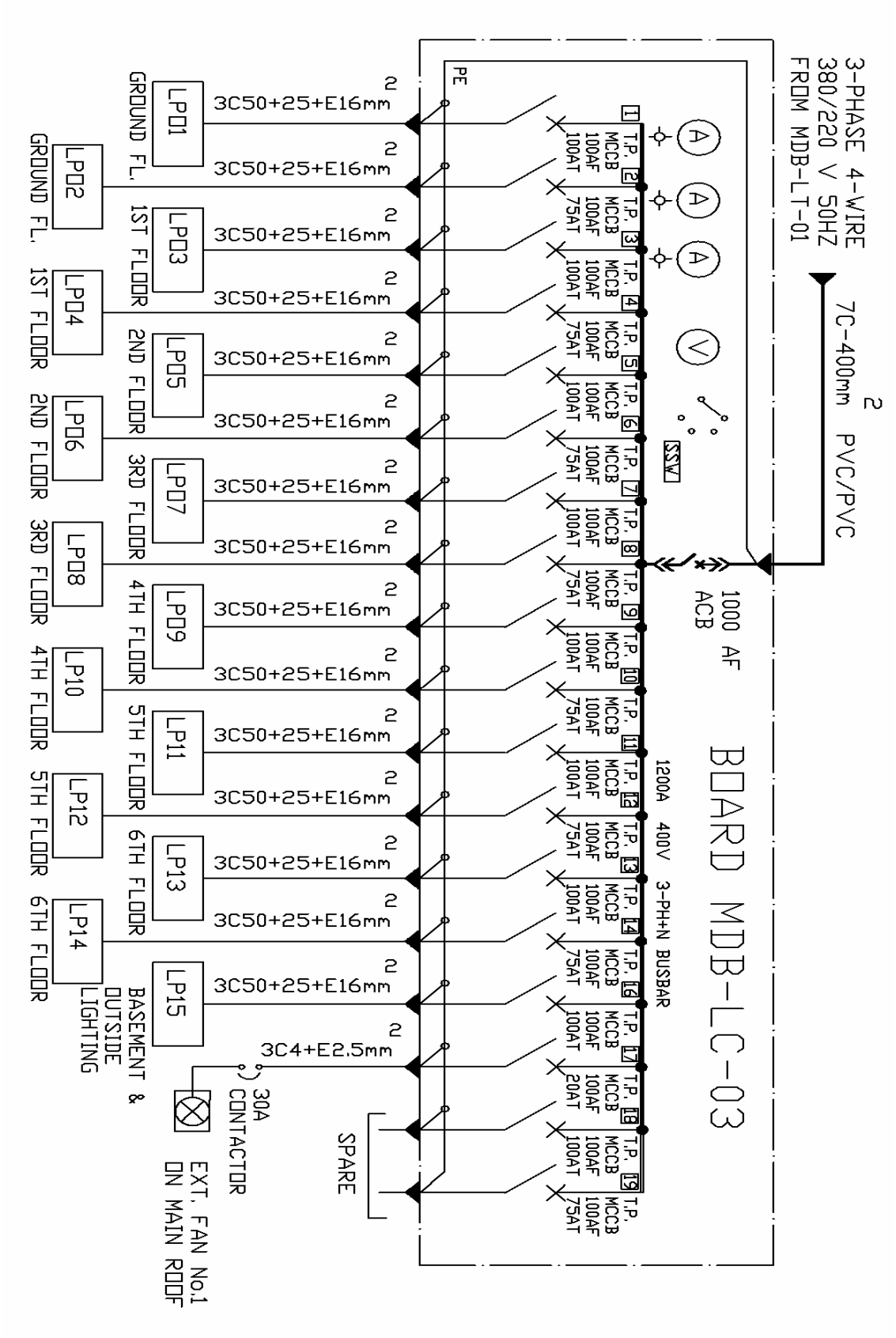
Fig.8 Large building distribution

Types of Distribution Boards in large buildings

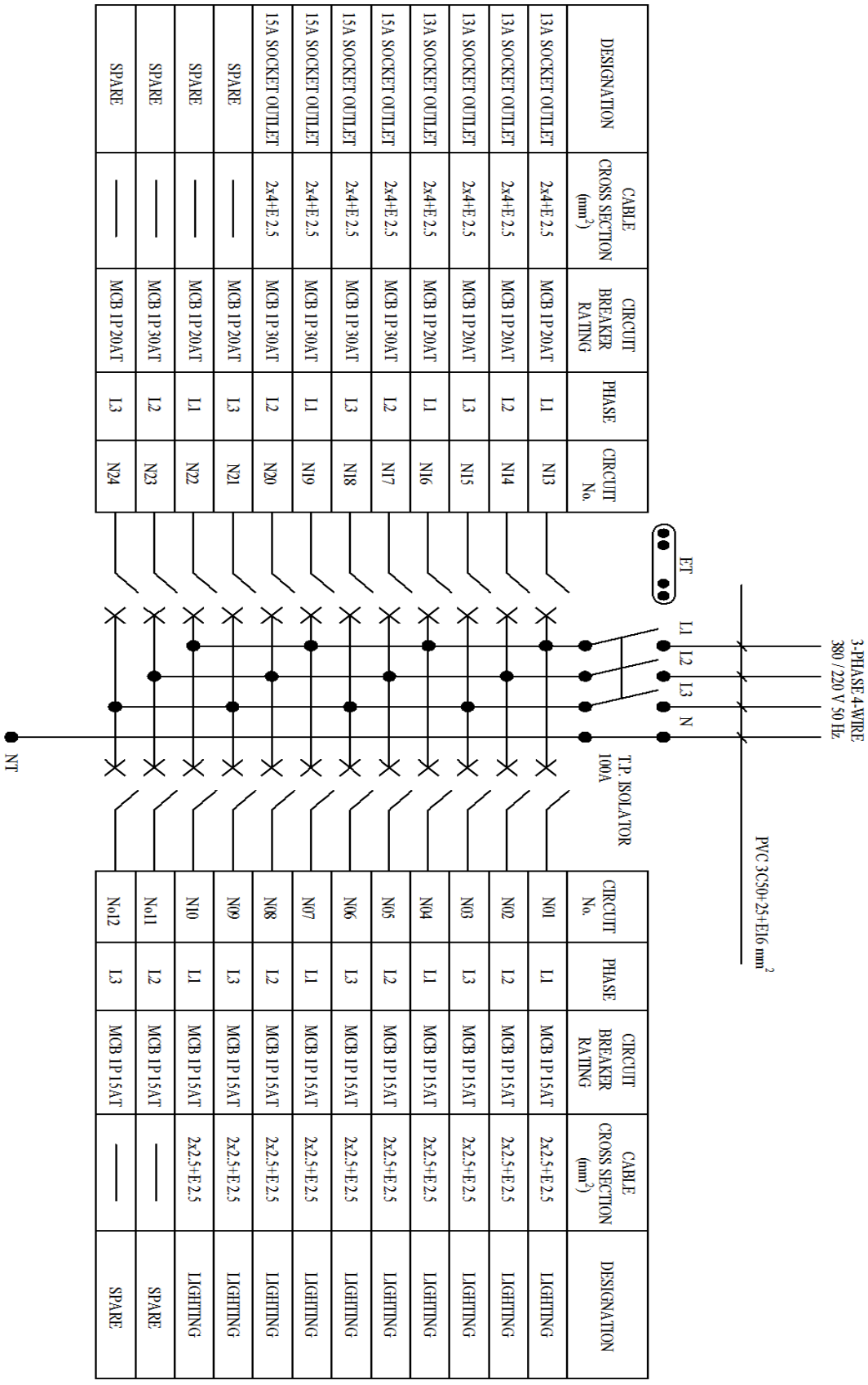
- L.T. Main Distribution Board
- Aux. Main Distribution Boards
- Sub-Distribution Board
- Final Sub-distribution boards
- Branch distribution panels
- Motor Control Centers (MCC)
- Special use distribution boards

L.T. Main Distribution Board

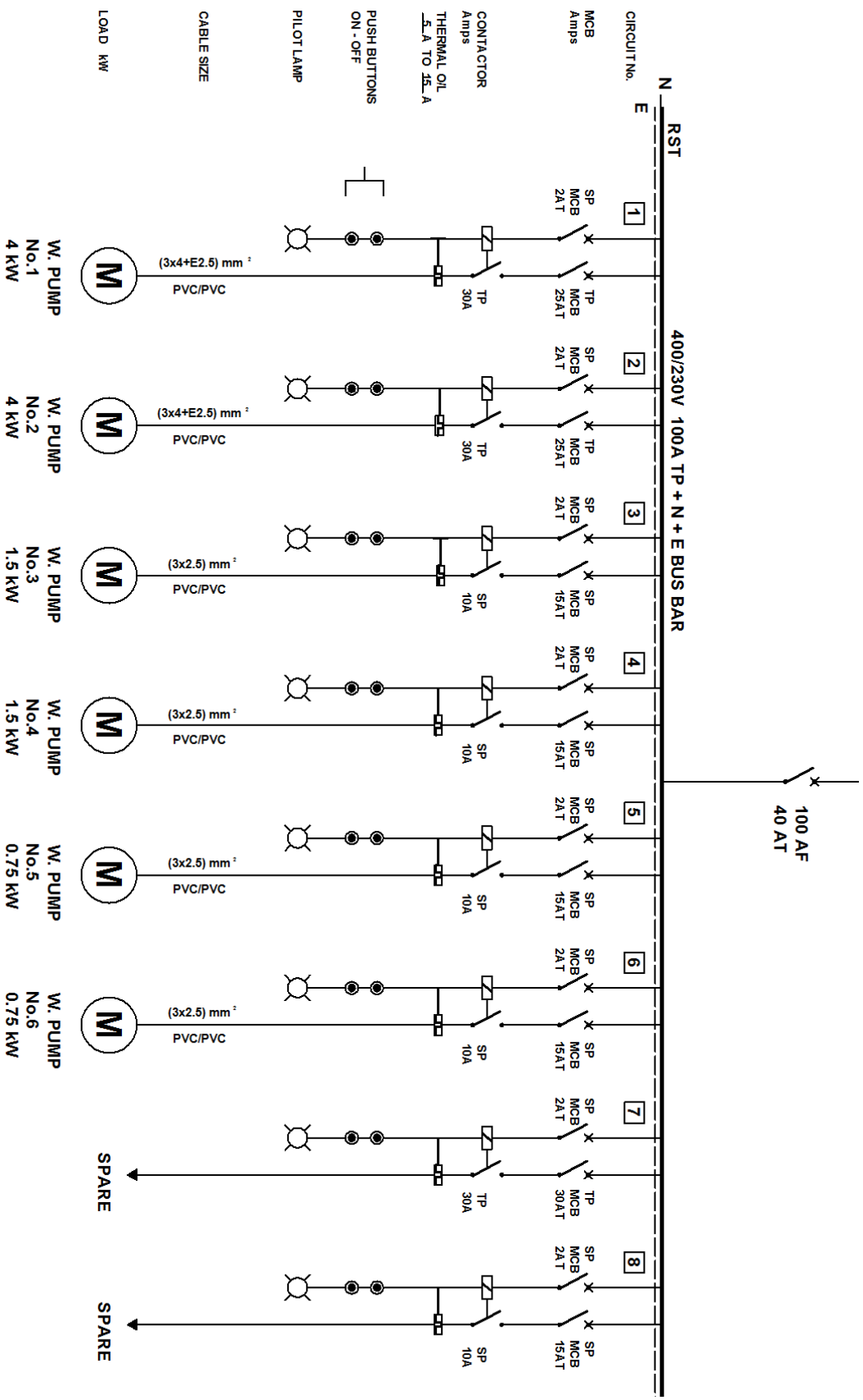




Aux. Main Distribution Boards


3-PHASE 4-WIRE
380 / 220 V 50 Hz
PVC 3C50+25+E16 mm2
ET
L1 L2 L3 N
T.P. ISOLATOR
100A
NT
DESIGNATION
CABLE CROSS SECTION (mm2)
CIRCUIT BREAKER RATING
PHASE
CIRCUIT No.
13A SOCKET OUTLET 2x4+E 2.5 MCB 1P 20AT L1 N13
13A SOCKET OUTLET 2x4+E 2.5 MCB 1P 20AT L2 N14
13A SOCKET OUTLET 2x4+E 2.5 MCB 1P 20AT L3 N15
13A SOCKET OUTLET 2x4+E 2.5 MCB 1P 20AT L1 N16
15A SOCKET OUTLET 2x4+E 2.5 MCB 1P 30AT L2 N17
15A SOCKET OUTLET 2x4+E 2.5 MCB 1P 30AT L3 N18
15A SOCKET OUTLET 2x4+E 2.5 MCB 1P 30AT L1 N19
15A SOCKET OUTLET 2x4+E 2.5 MCB 1P 30AT L2 N20
SPARE —— MCB 1P 20AT L3 N21
SPARE —— MCB 1P 20AT L1 N22
SPARE —— MCB 1P 30AT L2 N23
SPARE —— MCB 1P 20AT L3 N24
CIRCUIT No.
PHASE
CIRCUIT BREAKER RATING
CABLE CROSS SECTION (mm2)
DESIGNATION
N01 L1 MCB 1P 15AT 2x2.5+E 2.5 LIGHTING
N02 L2 MCB 1P 15AT 2x2.5+E 2.5 LIGHTING
N03 L3 MCB 1P 15AT 2x2.5+E 2.5 LIGHTING
N04 L1 MCB 1P 15AT 2x2.5+E 2.5 LIGHTING
N05 L2 MCB 1P 15AT 2x2.5+E 2.5 LIGHTING
N06 L3 MCB 1P 15AT 2x2.5+E 2.5 LIGHTING
N07 L1 MCB 1P 15AT 2x2.5+E 2.5 LIGHTING
N08 L2 MCB 1P 15AT 2x2.5+E 2.5 LIGHTING
N09 L3 MCB 1P 15AT 2x2.5+E 2.5 LIGHTING
N10 L1 MCB 1P 15AT 2x2.5+E 2.5 LIGHTING
No11 L2 MCB 1P 15AT —— SPARE
No12 L3 MCB 1P 15AT —— SPARE

Three-phase Final Distribution Board



Motor Control Centre (MCC)

INDUSTRIAL DISTRIBUTION BOARDS

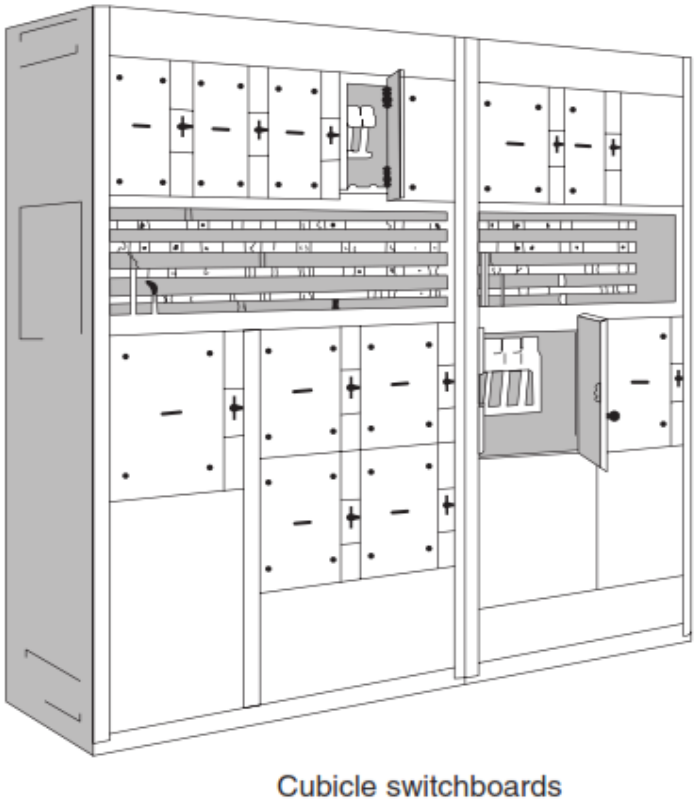


FIGURE . Industrial consumer's service position equipment.

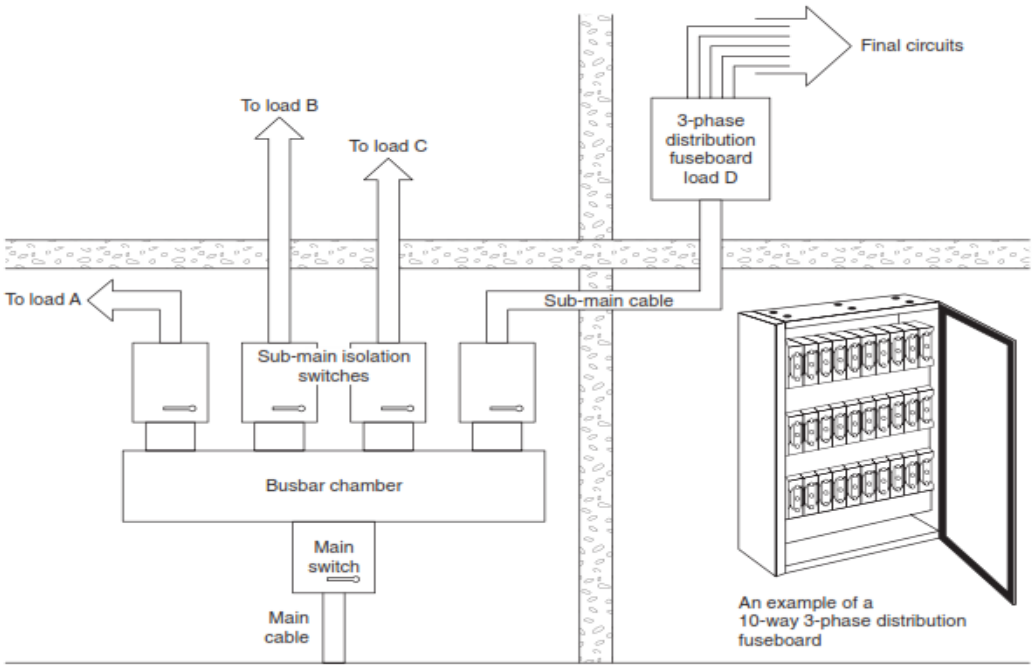


FIGURE .Typical distribution in commercial or industrial building.

DRAWINGS AND DIAGRAMS

Many different types of electrical drawing and diagram can be identified: layout, schematic, block, wiring and circuit diagrams. The type of diagram to be used in any particular application is the one which most clearly communicates the desired information.

1. LAYOUT DRAWINGS OR SITE PLAN

These are scale drawings based upon the architect's site plan of the build-ing and show the positions of the electrical equipment which is to be installed. The electrical equipment is identifi ed by a graphical symbol see Fig.1.
The standard symbols used by the electrical contracting industry are those recommended by the British Standard BS EN 60617, *Graphical Symbols for Electrical Power, Telecommunications and Electronic Diagrams.* Some of the more common electrical installation symbols are given in Fig.2 .

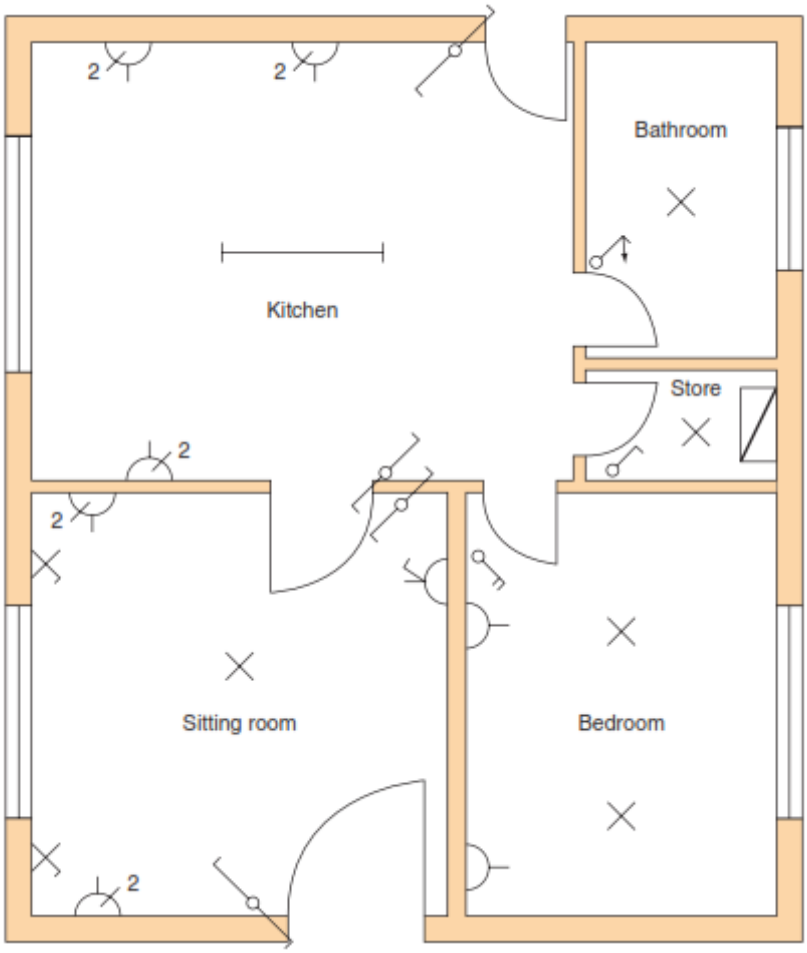


Fig.1 Layout drawing or site plan for electrical installation.

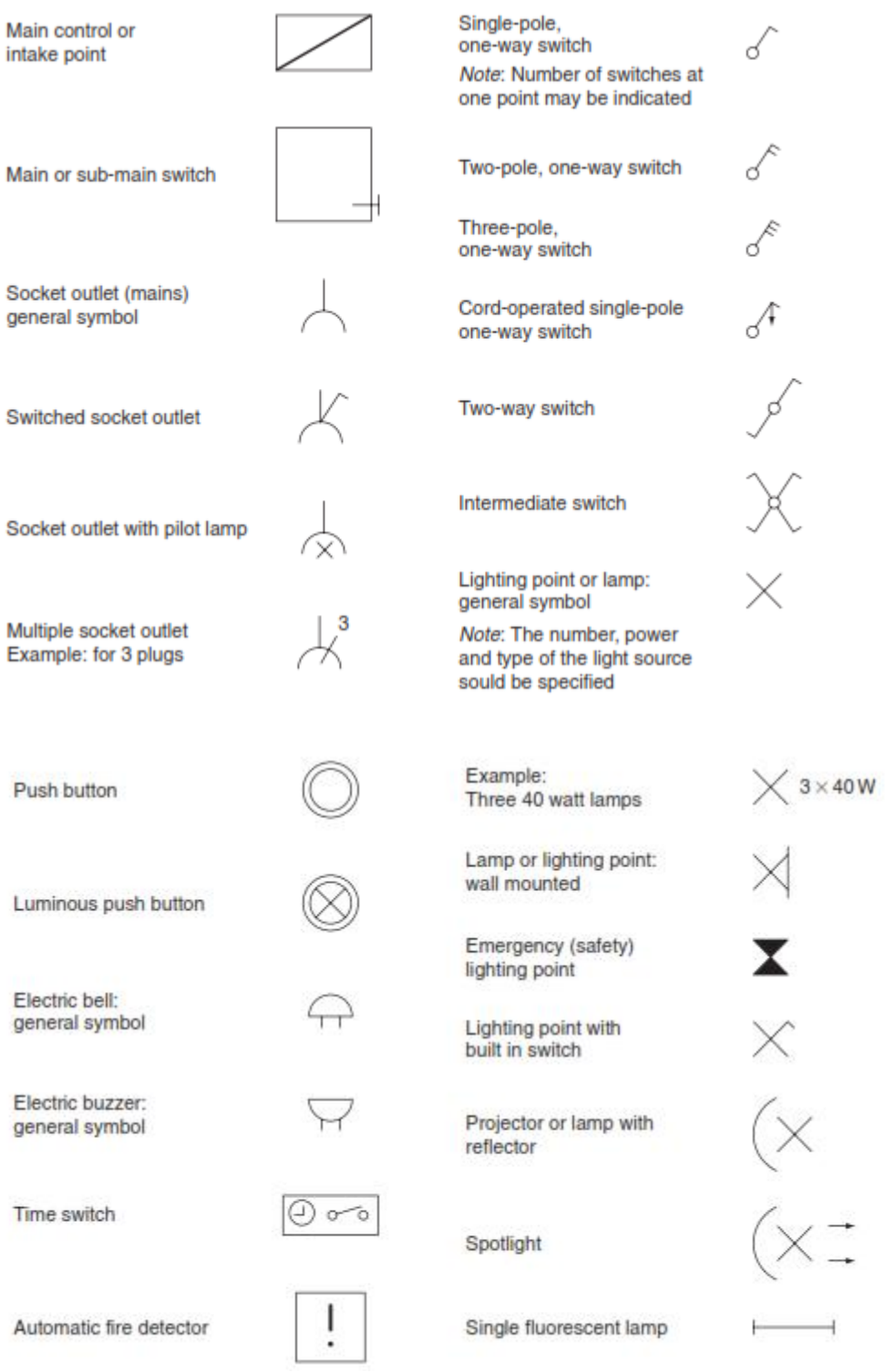

Main control or intake point
Main or sub-main switch
Socket outlet (mains) general symbol
Switched socket outlet
Socket outlet with pilot lamp
Multiple socket outlet Example: for 3 plugs
3
Push button
Luminous push button
Electric bell: general symbol
Electric buzzer: general symbol
Time switch
Automatic fire detector
Single-pole, one-way switch
Note: Number of switches at one point may be indicated
Two-pole, one-way switch
Three-pole, one-way switch
Cord-operated single-pole one-way switch
Two-way switch
Intermediate switch
Lighting point or lamp: general symbol
Note: The number, power and type of the light source sould be specified
Example: Three 40 watt lamps
3 × 40 W
Lamp or lighting point: wall mounted
Emergency (safety) lighting point
Lighting point with built in switch
Projector or lamp with reflector
Spotlight
Single fluorescent lamp

Fig 2 Electrical installation symbols according to British standard.

2. AS-FITTED DRAWINGS

When the installation is completed a set of drawings should be produced which indicate the final positions of all the electrical equipment. As the building and electrical installation progresses.

3. DETAIL DRAWINGS AND ASSEMBLY DRAWINGS

These are additional drawings produced by the architect to clarify some point of detail. For example, a drawing might be produced to give a fuller description of the suspended ceiling arrangements.

4. SCHEMATIC DIAGRAMS

A **schematic diagram** is a diagram in outline of, for example, a motor starter circuit. It uses graphical symbols to indicate the interrelationship of the electrical elements in a circuit. These help us to understand the working operation of the circuit.

An electrical schematic diagram looks very much like a circuit diagram. A mechanical schematic diagram gives a more complex description of the individual elements in the system, indicating, for example, acceleration, velocity, position, force sensing and viscous damping.

5.BLOCK DIAGRAMS

A **block diagram** is a very simple diagram in which the various items or pieces of equipment are represented by a square or rectangular box.

Three-phase short-circuit current (Isc) calculation at any point within a LV installation using impedance method

Calculation of Isc by the impedance method

In a 3-phase installation Isc at any point is given by:

$$Isc = \frac{V_{20}}{\sqrt{3}Z_T}$$

where

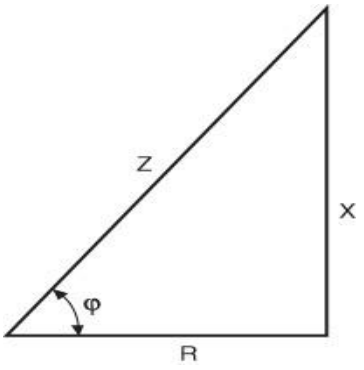
V_{20} (line-to- line voltage) corresponds to the transformer no-load voltage which is 3 to 5% greater than the on-load voltage across the terminals. For example, in 400 V networks, the **line-to-line** voltage adopted is V = 420 V and the line -to-neutral voltage is $V/\sqrt{3}$ = 242.5 V.

Or
V_{20} = line -to- line voltage of the open circuited secondary windings of the power supply transformer(s).
Z_T = total impedance per phase of the installation upstream of the fault location (in Ω)

Method of calculating Z_T

- Each component of an installation (MV network, transformer, cable, circuit-breaker, bus bar, and so on...) is characterized by its impedance Z, comprising an element of resistance (R) and an inductive reactance (X).
- It may be noted that capacitive reactances are not important in short-circuit current calculations.
- The parameters R, X and Z are expressed in ohms, and are related by the sides of a right angled triangle, as shown in the impedance diagram of **Figure 1**.

Fig.1 Impedance diagram



The method consists in dividing the network into convenient sections, and to calculate the R and X values for each.
Where sections are connected in series in the network, all the resistive elements in the section are added arithmetically; likewise for the reactances, to give R_T and X_T. The impedance (Z_T) for the combined sections concerned is then calculated from

$$Z_T = \sqrt{{R_T}^2 + {X_T}^2}$$

Any two sections of the network which are connected in parallel, can, if predominantly both resistive (or both inductive) be combined to give a single equivalent resistance (or reactance) as follows:
Let R1 and R2 be the two resistances connected in parallel, then the equivalent resistance R3 will be given by:

$$R_3 = \frac{R_1 \times R_2}{R_1 + R_2}$$ or for reactances $$X_3 = \frac{X_1 \times X_2}{X_1 + X_2}$$

It should be noted that the calculation of X_3 concerns only separated circuit without mutual inductance. If the circuits in parallel are close together the value of X_3 will be higher.

Determination of the impedance of each component

1- Network upstream of the MV/LV transformer

The 3-phase short-circuit fault level P_{SC}, in kA or in MVA[(i)] is given by the power supply authority concerned, from which an equivalent impedance can be deduced.

A formula which makes this deduction and at the same time converts the impedance to an equivalent value at LV is given, as follows:

where $$Zs = \frac{{V_o}^2}{P_{SC}}$$

Zs = impedance of the MV voltage network, expressed in milli-ohms
Vo = line-to-line no-load LV voltage, expressed in volts
Psc = MV 3-phase short-circuit fault level, expressed in kVA

- The upstream medium voltage (MV) side resistance Ra is generally found to be negligible compared with the corresponding Xa, the latter then being taken as the ohmic value for Za. If more accurate calculations are

necessary, Xa may be taken to be equal to 0.995 Za and Ra equal to 0.1 Xa.

- **Table-1** gives values for Ra and Xa corresponding to the most common MV[(ii)] short-circuit levels in utility power-supply networks, namely, 250 MVA and 500 MVA.

(i) Short-circuit MVA: $\sqrt{3}$ E_L Isc
where:

- E_L = line -to- line nominal system voltage expressed in kV (r.m.s.)
- Isc = 3-phase short-circuit current expressed in kA (r.m.s.)

(ii) up to 36 kV

Table-1The impedance of the MV network referred to the LV side of the

MV/LV transformer.

Psc	Vo (V)	Ra (mΩ)	Xa (mΩ)
250 MVA	420	0.07	0.7
500 MVA	420	0.035	0.351

2- The Transformer (see Table-2)

The impedance Ztr of a transformer, viewed from the LV terminals, is given by the formula: where:

$$Ztr = \frac{V_{20}{}^2}{Pn} \times \frac{Vsc}{100}$$

V_{20} = open-circuit secondary line-to- line voltage expressed in volts.
Pn = rating of the transformer (in kVA).
Vsc = the short-circuit impedance voltage of the transformer expressed in %.
The transformer windings resistance Rtr can be derived from the total losses as follows:

$$Rtr = \frac{Pcu \times 10^3}{3In^2}$$ in milli-ohms

where
Pcu = total losses in watts
In = nominal full-load current in amps
Rtr = resistance of one phase of the transformer in milli-ohms (the LV and

corresponding MV

winding for one LV phase are included in this resistance value).

$$Xtr = \sqrt{Ztr^2 - Rtr^2}$$

For an approximate calculation Rtr may be ignored since X ≈ Z in standard distribution type transformers.

Table -2 : *Resistance, reactance and impedance values for typical distribution 400 V transformers with MV windings ≤20 kV*

Rated Power (kVA)	Oil-immersed				Cast-resin			
	Usc (%)	**Rtr (mΩ)**	**Xtr (mΩ)**	**Ztr (mΩ)**	**Usc (%)**	**Rtr (mΩ)**	**Xtr (mΩ)**	**Ztr (mΩ)**
100	4	37.9	59.5	70.6	6	37.0	99.1	105.8
160	4	16.2	41.0	44.1	6	18.6	63.5	66.2
200	4	11.9	33.2	35.3	6	14.1	51.0	52.9
250	4	9.2	26.7	28.2	6	10.7	41.0	42.3
315	4	6.2	21.5	22.4	6	8.0	32.6	33.6
400	4	5.1	16.9	17.6	6	6.1	25.8	26.5
500	4	3.8	13.6	14.1	6	4.6	20.7	21.2
630	4	2.9	10.8	11.2	6	3.5	16.4	16.8
800	6	2.9	12.9	13.2	6	2.6	13.0	13.2
1,000	6	2.3	10.3	10.6	6	1.9	10.4	10.6
1,250	6	1.8	8.3	8.5	6	1.5	8.3	8.5
1,600	6	1.4	6.5	6.6	6	1.1	6.5	6.6
2,000	6	1.1	5.2	5.3	6	0.9	5.2	5.3

3 - Circuit-breakers

In LV circuits, the impedance of circuit-breakers upstream of the fault location must be taken into account. The reactance value conventionally assumed is 0.15 mΩ per CB, while the resistance is neglected.

4 - Busbars

The resistance of bus bars is generally negligible, so that the impedance is practically all reactive, and amounts to approximately 0.15 mΩ / meter length for LV bus bars (doubling the spacing between the bars increases the reactance by about 10% only).

5 - Circuit conductors

The resistance of a conductor is given by the formula: $Rc = \rho \frac{L}{S}$
where

ρ = the resistivity constant of the conductor material at the normal operating temperature being:
- 22.5 mΩ.mm^2/m for copper
- 36 mΩ.mm^2/m for aluminum

L = length of the conductor in m
S = c.s.a. of conductor in mm^2

Table - 3: *Values of ρ as a function of the temperature, cable insulation and cable core material, according to IEC60909-0 and Cenelec TR 50480.*

	20 °C	EPR/XLPE 90 °C	PVC 70 °C
Copper	18.51	23.6928	22.212
Alu	29.41	37.6448	35.292

L = length of the conductor in m
S = c.s.a. of conductor in mm^2

Cable reactance values can be obtained from the manufacturers. For c.s.a. of less than 50 mm^2 reactance may be ignored. In the absence of other information, a value of 0.08 mΩ / meter may be used (for 50 Hz systems) or 0.096 mΩ/meter (for 60 Hz systems). For prefabricated bus-trunking and similar pre-wired ducting systems, the manufacturer should be consulted.

6 - Motors

At the instant of short-circuit, a running motor will act (for a brief period) as a generator, and feed current into the fault.
In general, this fault-current contribution may be ignored**. However, if the total power of motors running simultaneously is higher than 25% of the total power of transformers, the influence of motors must be taken into account.**
Their total contribution can be estimated from the formula:
I_{scm} = 3.5 In from each motor i.e. 3.5(m In) for m similar motors operating concurrently.
The motors concerned will be the 3-phase motors only; **single-phase-motor contribution being insignificant.**

7 - Fault-arc resistance

Short-circuit faults generally form an arc which has the properties of a resistance. The resistance is not stable and its average value is low, but at low voltage this resistance is sufficient to reduce the fault-current to some extent. Experience has shown that a reduction of the order of 20% may be expected. This phenomenon will effectively ease the current-breaking duty of a CB, but affords no relief for its fault-current making duty.

Example 1: For the installation Network shown in Fig.2 make short circuit calculation from MV take-off point to the final distribution board. Assume all cables are XLPE type.

Solution:

The short circuit current

Is given by

$$Isc = \frac{420}{\sqrt{3}\sqrt{R_T{}^2 + X_T{}^2}}$$

1-To calculate the short circuit current at LV B/B -1,The total Impedance Z_T from point **A** to point **B** must be found .

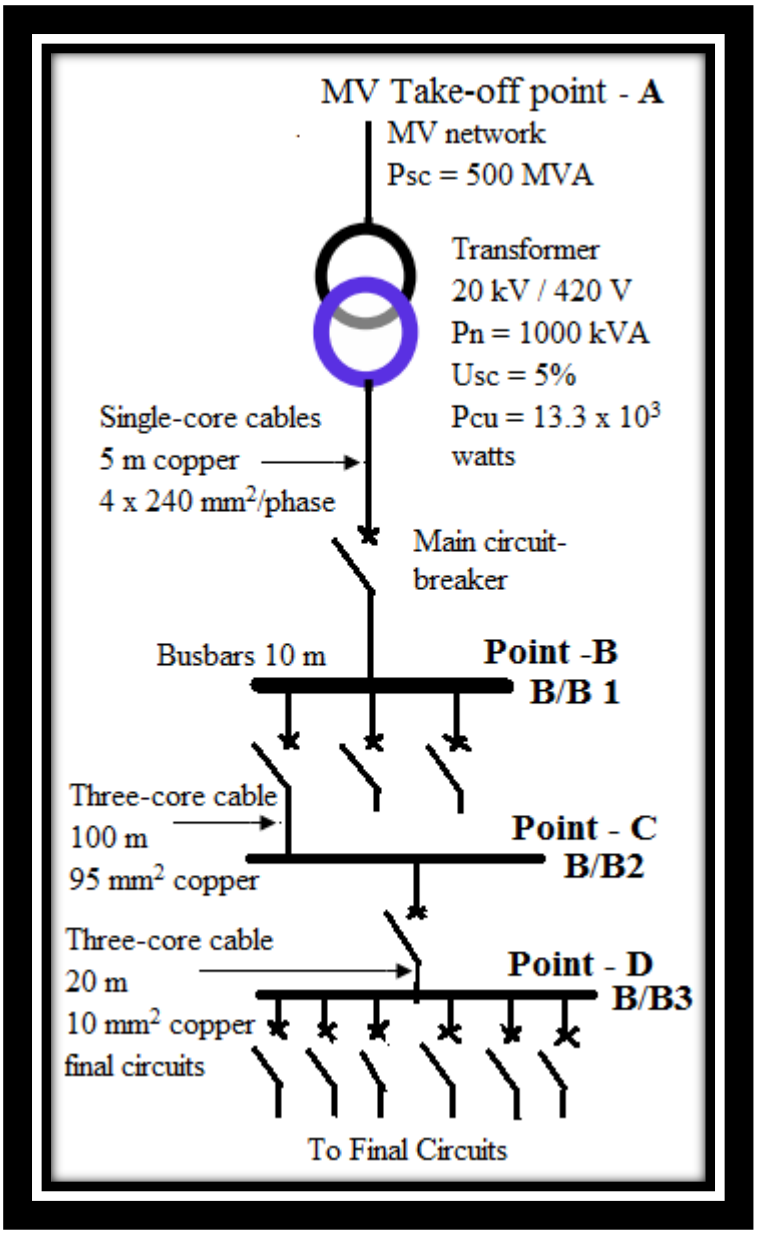


Fig.2

- **Network upstream of the MV/LV transformer**
  From Table – 1 ,for short-circuit level of 500MVA.

Ra = 0.035 **(mΩ) , Xa** = 0.351 **(mΩ)**

- The Transformer : from table -2 , for 1000kVA rating ,

  Rtr = 2.24 **(mΩ) , Xtr** = 8.10 **(mΩ)**

- For the single-core cables 5 m copper 4 x 240 mm^2/phase : $Rc = \rho\frac{L}{S}$

  From Table -3: Let the cable type XLPE , ρ = 23.7 approx.,hence,

  L = 5 m and S = 4x240 mm^2, therefore ,

  $$Rc = \frac{23.7}{4} \times \frac{5}{240} = 0.12$$ **(mΩ)**

  Xc = 0.08 x 5 = 0.40 **(mΩ)** [Cable reactance values can be obtained from the manufacturers. For c.s.a. of less than 50 mm^2 reactance may be ignored. In the absence of other information, a value of 0.08 mΩ / metre may be used (for 50 Hz systems)]

- For the main circuit breaker: R and X are Not considered in practice.

Now from point A to point B ,

$R_{T1} = R_a + R_{tr} + R_c = 0.035 + 2.24 + 0.12 = 2.4$ **(mΩ)**

$X_{T1} = X_a + X_{tr} + X_c = 0.351 + 8.10 + 0.4 = 8.85$**(mΩ)**

$$I_{sc1} = \frac{420}{\sqrt{3}\sqrt{R_{T1}^2 + X_{T1}^2}} = \frac{420}{\sqrt{3}\sqrt{2.4^2 + 8.85^2}} = 26\ kA$$

2 – Short circuit calculation at point C: Bus bar B/B1,10 m , Not considered in practice .

For the three-core XLPE cable 100 m , 95 mm^2 copper

$$Rc_2 = 23.7 \times \frac{100}{95} = 25$$ **(mΩ)** , Xc2 = 100 x 0.08 = 8 **(mΩ)**

Hence RT2 = RT1 + Rc2 = 25 + 2.4 = 27.4 **(mΩ)**

XT2 = XT1 + Xc2 = 8.85 + 8 = 16.85 **(mΩ)**

$$I_{sc2} = \frac{420}{\sqrt{3}\sqrt{R_{T2}^2 + X_{T2}^2}} = \frac{420}{\sqrt{3}\sqrt{27.4^2 + 16.85^2}} = 7.54\ kA$$

3- Short circuit calculation at point D: Bus bar B/B2 , Not considered in practice .Only the impedance of the three-core cable ,20 m , 10 mm^2 copper,

$$Rc3 = 23.7 \times \frac{20}{10} = 47.4 \quad \textbf{(m}\Omega\textbf{)}$$

Xc3 = 20 x 0.08 = 1.6 **(mΩ)**

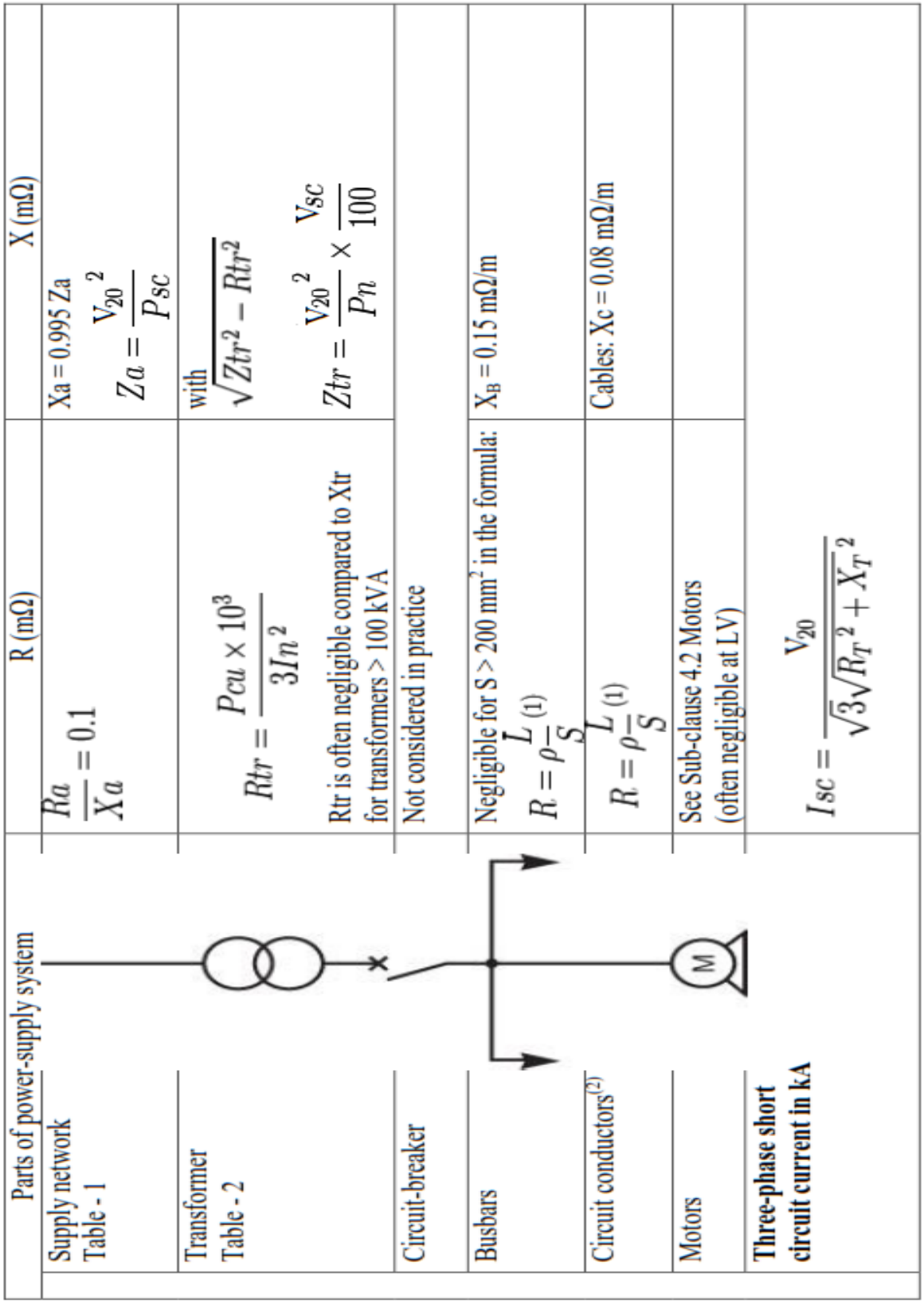
Hence RT3 = RT2 + Rc3 = 27.4 + 47.4 = 74.8 **(mΩ)**

XT3 = XT2 + Xc3 = 16.85 + 1.6 = 18.45 **(mΩ)**

$$I_{sc3} = \frac{420}{\sqrt{3}\sqrt{R_{T3}^2 + X_{T3}^2}} = \frac{420}{\sqrt{3}\sqrt{74.8^2 + 18.45^2}} = 3.15\ kA$$

Summary

Fig.3 gives design table of impedances for different parts of a power-supply system



Parts of power-supply system	R (mΩ)	X (mΩ)
Supply network Table - 1	$\frac{Ra}{Xa} = 0.1$	Xa = 0.995 Za $Za = \frac{V_{20}^{\ 2}}{Psc}$
Transformer Table - 2	$Rtr = \frac{Pcu \times 10^3}{3In^2}$ Rtr is often negligible compared to Xtr for transformers > 100 kVA	with $\sqrt{Ztr^2 - Rtr^2}$ $Ztr = \frac{V_{20}^{\ 2}}{Pn} \times \frac{Vsc}{100}$
Circuit-breaker	Not considered in practice	
Busbars	Negligible for S > 200 mm² in the formula: $R = \rho\frac{L}{S}$ (1)	$X_B = 0.15$ mΩ/m
Circuit conductors(2)	$R = \rho\frac{L}{S}$ (1)	Cables: Xc = 0.08 mΩ/m
Motors	See Sub-clause 4.2 Motors (often negligible at LV)	
Three-phase short circuit current in kA	$Isc = \frac{V_{20}}{\sqrt{3}\sqrt{R_T^{\ 2} + X_T^{\ 2}}}$	

Fig. 3: *Recapitulation table of impedances for different parts of a power-supply system*

Symbols for table given in Fig.3:

V_{20}: Phase-to-phase no-load secondary voltage of MV/LV transformer (in volts).
Psc: 3-phase short-circuit power at MV terminals of the MV/LV transformers (in kVA).
Pcu: 3-phase total losses of the MV/LV transformer (in watts).
Pn: Rating of the MV/LV transformer (in kVA).
Vsc: Short-circuit impedance voltage of the MV/LV transfomer (in %).
R_T : Total resistance. X_T: Total reactance
(1) ρ = resistivity at normal temperature of conductors in service

- ρ = 22.5 mΩ x mm^2/m for copper
- ρ = 36 mΩ x mm^2/m for aluminium

(2) If there are several conductors in parallel per phase, then divide the resistance of one conductor by the number of conductors. The reactance remains practically unchanged.

Standard values for lighting of indoor and outdoor workplaces and sports facility lighting Em

Traffic zones and general areas inside buildings

Traffic zones	
• Circulation areas and corridors	100
• Stairs, escalators, travolators	150
• Loading ramps/bays	150
Rest, sanitation and first aid rooms	
• Canteens, pantries	200
• Rest rooms	100
• Rooms for physical exercise	300
• Cloakrooms, washrooms, bathrooms, toilets	200
• Sick bay	500
• Rooms for medical attention	500
Control rooms	
• Plant rooms, switch gear rooms	200
• Telex, post room, switchboard	500
Store rooms, cold stores	
• Store and stockrooms	100
• Dispatch packing handling areas	300
Storage rack areas	
• Gangways: unmanned	20
• Gangways: manned	150
• Control stations	150

Industrial activities and crafts

Type of interior, task or activity	$\bar{E}_m$
Agriculture	
• Loading and operating of goods, handling equipment and machinery	200
• Buildings for livestock	50
• Sick animal pens; calving stalls	200
• Feed preparation; dairy; utensil washing	200
Bakeries	
• Preparation and baking	300
• Finishing, glazing, decorating	500
Cement, cement goods, concrete, bricks	
• Drying	50
• Preparation of materials; work on kilns and mixers	200
• General machine work	300
• Rough forms	300
Ceramics, tiles, glass, glassware	
• Drying	50
• Preparation, general machine work	300
• Enamelling, rolling, pressing, shaping simple parts, glazing, glass blowing	300
• Grinding, engraving, glass polishing, shaping precision parts, manufacture of glass instruments	750
• Grinding of optical glass, crystal, hand grinding and engraving	750
• Precision work e.g. decorative grinding, hand painting	1000
• Manufacture of synthetic precious stones	1500
Chemical, plastics and rubber industry	
• Remote-operated processing installations	50
• Processing installations with limited manual intervention	150
• Constantly manned work places in processing installations	300
• Precision measuring rooms, laboratories	500
• Pharmaceutical production	500
• Tyre production	500
• Colour inspection	1000
• Cutting, finishing, inspection	750

Electrical industry	
• Cable and wire manufacture	300
• Winding:	
– large coils	300
– medium-sized coils	500
– small coils	750
• Coil impregnating	300
• Galvanising	300
• Assembly work:	
– rough e.g. large transformers	300
– medium e.g. switchboards	500
– fine e.g. telephones	750
– precision e.g. measuring equipment	1000
• Electronic workshops, testing, adjusting	1500

Type of interior, task or activity	$\bar{E}_m$
• Laboratories	500
• Colour inspection	1000
Foundries and metal casting	
• Man-size underfloor tunnels, cellars, etc.	50
• Platforms	100
• Sand preparation	200
• Dressing room	200
• Work places at cupola and mixer	200
• Casting bay	200
• Shake out areas	200
• Machine moulding	200
• Hand and core moulding	300
• Die casting	300
• Model building	500

Metal working and processing	
• Open die forging	200
• Drop forging	300
• Welding	300
• Rough and average machining: tolerances ≥ 0.1 mm	300
• Precision machining; grinding: tolerances < 0.1 mm	500
• Scribing; inspection	750
• Wire and pipe drawing shops; cold forming	300
• Plate machining: thickness ≥ 5 mm	200

Food stuffs and luxury food industry	
• Work places and zones in – breweries, malting floor – for washing, barrel filling, cleaning, sieving, peeling – cooking in preserve and chocolate factories – work places and zones in sugar factories – for drying and fermenting raw tobacco, fermentation cellar	200
• Sorting and washing of products, milling, mixing, packing	300
• Work places and critical zones in slaughter houses, butchers, dairies mills, on filtering floor in sugar refineries	500
• Cutting and sorting of fruit and vegetables	300
• Manufacture of delicatessen foods, kitchen work, manufacture of cigars and cigarettes	500
• Inspection of glasses and bottles, product control, trimming, sorting, decoration	500

Hairdressers	
• Hairdressing	500
Jewellery manufacturing	
• Working with precious stones	1500
• Manufacture of jewellery	1000
• Watch making (manual)	1500
• Watch making (automatic)	500
Laundries and dry cleaning	
• Goods in, marking and sorting	300
• Washing and dry cleaning	300
• Ironing, pressing	300
• Inspection and repairs	750
Leather and leather goods	
• Work on vats, barrels, pits	200
• Fleshing, skiving, rubbing, tumbling of skins	300
• Saddlery work, shoe manufacture: stitching, sewing, polishing, shaping, cutting, punching	500
• Sorting	500
• Leather dyeing (machine)	500
• Quality control	1000
• Colour inspection	1000
• Shoe making	500
• Glove making	500
Printers	
• Cutting, gilding, embossing, block engraving, work on stones and platens, printing machines, matrix making	500
• Paper sorting and hand printing	500
• Type setting, retouching, lithography	1000
• Colour inspection in multicoloured printing	1500
• Steel and copper engraving	2000
Rolling mills, iron and steel works	
• Production plants without manual operation	50
• Production plants with occasional manual operation	150
• Production plants with continuous manual operation	200
• Slab Store	50
• Furnaces	200
• Mill train; coiler; shear line	300
• Control platforms; control panels	300
• Test, measurement and inspection	500

Paper and paper goods	
• Edge runners, pulp mills	200
• Paper manufacture and processing, paper and corrugating machines, cardboard manufacture	300
• Standard bookbinding work, e.g. folding, sorting, gluing, cutting, embossing, sewing	500
Power stations	
• Fuel supply plant	50
• Boiler house	100
• Machine halls	200
• Side rooms, e.g. pump rooms, condenser rooms etc.; switchboards (inside buildings)	200
• Control rooms	500
• Outdoor switch gear	20

Places of public assembly

General areas	
• Entrance halls	100
• Cloakrooms	200
• Lounges	200
• Ticket offices	300
Restaurants and hotels	
• Reception/cashier desk, porters desk	300
• Kitchen	500
• Restaurant, dining room, function room	–
• Self-service restaurant	200
• Buffet	300
• Conference rooms	500
• Corridors	100
Theatres, concert halls, cinemas	
• Practice rooms, dressing rooms	300
Trade fairs, exhibition halls	
• General lighting	300

Vehicle construction	
• Body work and assembly	500
• Painting, spraying chamber, polishing chamber	750
• Painting: touch-up, inspection	1000
• Upholstery manufacture (manned)	1000
• Final inspection	1000
Wood working and processing	
• Automatic processing e.g. drying, plywood manufacturing	50
• Steam pits	150
• Saw frame	300
• Work at joiner's bench, gluing, assembly	300
• Polishing, painting, fancy joinery	750
• Work on wood working machines e.g. turning, fluting, dressing, rebating, grooving, cutting, sawing, sinking	500
• Selection of veneer woods	750
• Marquetry, inlay work	750
• Quality control, inspection	1000

Museums	
• Exhibits, insensitive to light	
• Light sensitive exhibits	
Libraries	
• Bookshelves	200
• Reading area	500
• Counters	500
Public car parks (indoor)	
• In/out ramps (during the day)	300
• In/out ramps (at night)	75
• Traffic lanes	75
• Parking areas	75
• Ticket office	300

• Practical rooms and laboratories	500
• Handicraft rooms	500
• Teaching workshop	500
• Music practice rooms	300
• Computer practice rooms (menu driven)	300
• Language laboratory	300
• Preparation rooms and workshops	500
• Entrance halls	200
• Circulation areas, corridors	100
• Stairs	150
• Student common rooms and assembly halls	200
• Teachers rooms	300
• Library: bookshelves	200
• Library: reading areas	500
• Stock rooms for teaching materials	100
• Sports halls, gymnasiums, swimming pools (general use)	300
• School canteens	200
• Kitchen	500

Educational premises

Nursery school, play school

• Play room	300
• Nursery	300
• Handicraft room	300

Educational buildings

• Classrooms, tutorial rooms	300
• Classroom for evening classes and adults education	500
• Lecture hall	500
• Black board	500
• Demonstration table	500
• Art rooms	500
• Art rooms in art schools	750
• Technical drawing rooms	750

Health care premises

Rooms for general use	
• Waiting rooms	200
• Corridors: during the day	200
• Corridors: during the night	50
• Day rooms	200
Staff rooms	
• Staff office	500
• Staff rooms	300
Wards, maternity wards	
• General lighting	100
• Reading lighting	300
• Simple examinations	300
• Examination and treatment	1000
• Night lighting, observation lighting	5
• Bathrooms and toilets for patients	200
Examination rooms (general)	
• General lighting	500
• Examination and treatment	1000
Eye examination rooms	
• General lighting	300
• Examination of the outer eye	1000
• Reading and colour vision tests with vision charts	500
Ear examination rooms	
• General lighting	300
• Ear examination	1000
Operating areas	
• Pre-op and recovery rooms	500
• Operating theatre	1000
• Operating cavity	
Intensive care unit	
• General lighting	100
• Simple examinations	300
• Examination and treatment	1000
• Night watch	20
Dentists	
• General lighting	500
• At the patient	1000
• Operating cavity	5000
• White teeth matching	5000
Laboratories and pharmacies	

Scanner rooms	
• General lighting	300
• Scanners with image enhancers and television systems	50
Delivery rooms	
• General lighting	300
• Examination and treatment	1000
Treatment rooms (general)	
• Dialysis	500
• Dermatology	500
• Endoscopy rooms	300
• Plaster rooms	500
• Medical baths	300
• Massage and radiotherapy	300

• Air traffic control tower	500
• Testing and repair hangars	500
• Engine test areas	500
• Measuring areas in hangars	500

الجدول (٧ – ١)

طلب التيار المفترض لنقط الإفادة والمعدات المستخدمة للتيار.

نقط الإفادة والمعدات المستخدمة للتيار	طلب التيار المفترض
مقابس عدا عن المقابس ذات التيار المقرر (2) أمبير وعدا عن المقابس ذات التيار المقرر (13) أمبير. انظر الملاحظة (١).	- التيار المقرر.
مقابس ذات تيار مقرر (13) أمبير. انظر الملاحظة (٢).	تيار يكافئ الحمل المربوط بحد أدنى (250) فولط لكل مقبس، على ألا يزيد عدد المقابس عن عدد المقابس الموزعة حسب الترتيب القياسي للدارات الكهربائية كما هو وارد في المادة (٤/٧).
ساعة كهربائية ، وحدة تغذية لماكينة حلاقة (تطابق المواصفة القياسية البريطانية (BS 3535))، مقبس لماكينة حلاقة (يطابق المواصفات القياسية البريطانية (BS 4573)، محول جرس كهربائي، ومعدات مستخدمة للتيار ذات مقرر لا يزيد عن (5) فولط أمبير.	يمكن إهمالها.
أجهزة طبخ منزلية.	أول (10) أمبير من التيار المقرر + 30 % من باقي التيار المقرر + (5) أمبير إذا كان في وحدة التحكم مقبس.
جميع المعدات الثابتة.	التيار المقرر حسب المواصفات القياسية البريطانية، أو التيار العادي.

ملاحظة:

(١) انظر المادة (٤/٧) فيما يتعلق بتصميم الدارات القياسية باستعمال مقابس مطابقة للمواصفات القياسية البريطانية (BS 1363-2) و (BS 4343).

(٢) يجب أن تكون الدارات النهائية للإضاءة التفريغية مرتبة بحيث تكون قادرة على حمل التيار الكلي المستقر أي حمل المصباح/المصابيح وأي طقم مرافق وكذلك تياراتها التوافقية. وحيث لا تتوفر معلومات ذات دقة أكثر فإن الطلب بالفولط أمبير يؤخذ على أنه القدرة المقررة للمصباح بالواط مضروبة في عامل لا يقل عن (1.8). وعامل الضرب هذا مبني على افتراض أن الدارة معدلة لعامل قدرة متأخر (Lagging) لا يقل عن (0.85) وتأخذ الثقة في طقم التحكم والتيار التوافقي في الحسبان.

الجدول (٧ – ٢)

السماحات للتشتت (التطابق).

الغرض من الدارة النهائية المغذاة من موصلات أو طقم مبدلات ينطبق عليها التشتت	نوع المرفق		
	تمديدات منزلية منفردة شاملة مساكن منفردة من مجموعات سكنية.	متاجر صغيرة، مخازن، مكاتب ومرافق تجارية.	فنادق صغيرة، بيوت سكنية، بيوت ضيافة، ... الخ
١. إنارة	66 بالمائة من طلب التيار الكلي	90 بالمائة من طلب التيار الكلي	75 بالمائة من طلب التيار الكلي.
٢. تدفئة وقدرة (انظر البندين (٣) و (٨) أدناه)	100 بالمائة من طلب التيار الكلي حتى (10) أمبير + 50 بالمائة من أي طلب تيار زيادة عن (10) أمبير	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 75 بالمائة من تيار الحمل الكلي للأجهزة المتبقية	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 80 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر + 60 بالمائة من الحمل الكلي للأجهزة الباقية.
٣. أجهزة الطبخ	(10) أمبير + 30 بالمائة من تيار الحمل الكامل لأجهزة الطبخ المربوطة زيادة عن (10) أمبير + (5) أمبير إذا كانت وحدة التحكم تحتوي على مقبس.	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 80 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر + 60 بالمائة من تيار الحمل الكامل لكل من الأجهزة الباقية.	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 80 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر+ 60 بالمائة من تيار الحمل الكامل للأجهزة الباقية.

تابع للجدول (٧ – ٢)

السماحات للتشتت (التطابق).

الغرض من الدارة النهائية المغذاة من موصلات أو طقم مبدلات ينطبق عليها التشتت	نوع المرفق		
	تمديدات منزلية منفردة شاملة مساكن منفردة من مجموعات سكنية	مبانٍ تجارية صغيرة، مخازن، مكاتب ومرافق تجارية (رجال أعمال)	فنادق صغيرة، بيوت سكنية، بيوت ضيافة، ... الخ
٤. محركات (عدا عن محركات المصاعد التي تخضع لاعتبارات خاصة)	غير قابلة للتطبيق	100 بالمائة من تيار الحمل الكامل لأكبر محرك + 80 بالمائة من تيار الحمل الكامل للمحرك الذي يليه في الكبر + 60 بالمائة من تيار الحمل الكامل للمحركات المتبقية.	100 بالمائة من تيار الحمل الكامل لأكبر محرك + 50 بالمائة من تيار الحمل الكامل لباقي المحركات.
٥. سخانات الماء (النوع اللحظي*)	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 100 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر + 25 بالمائة من تيار الحمل الكامل للأجهزة المتبقية.	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 100 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر + 25 بالمائة من تيار الحمل الكامل للأجهزة المتبقية.	100 بالمائة من تيار الحمل الكامل لأكبر جهاز + 100 بالمائة من تيار الحمل الكامل للجهاز الذي يليه في الكبر + 25 بالمائة من تيار الحمل الكامل للأجهزة المتبقية.
٦. سخانات الماء (ذات التحكم عن طريق ثيرموستات)	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +	لا يسمح بأي تشتت، إذ يستعمل الحمل الكامل. +

تابع للجدول (٧ – ٢)

السماحات للتشتت (التطابق).

الغرض من الدارة النهائية المغذاة من موصلات أو طقم مبدلات ينطبق عليها التشتت	نوع المرفق		
	تمديدات منزلية منفردة شاملة مساكن منفردة من مجموعات سكنية.	متاجر صغيرة، مخازن، مكاتب ومرافق تجارية، (رجال أعمال)	فنادق صغيرة، بيوت سكنية، بيوت ضيافة، ... الخ
٧. تمديدات تدفئة للأرضية	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل +	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +
٨. تمديدات تدفئة عن طريق تخزين حراري فضائي	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل +	لا يسمح بأي تشتت؛ إذ يستعمل الحمل الكامل. +
٩. ترتيبات قياسية للدارات النهائية طبقا للمادة (٤/٧).	100 بالمائة من طلب التيار لأكبر دارة + 40 بالمائة من طلب التيار لكل دارة أخرى	100 بالمائة من طلب التيار لأكبر دارة + 50 بالمائة من طلب التيار لكل دارة أخرى.	
١٠. مقابس عدا عن تلك الواردة في (٩) أعلاه والمعدات الثابتة عدا عن تلك المجدولة أعلاه	100 بالمائة من طلب التيار لأكبر نقطة إفادة +40 بالمائة من طلب التيار لكل نقطة إفادة أخرى.	100 بالمائة من طلب التيار لأكبر نقطة إفادة +70 بالمائة من طلب التيار لكل نقطة إفادة أخرى.	100 بالمائة من طلب التيار لأكبر نقطة إفادة + 75 بالمائة من طلب التيار لكل نقطة إفادة في الغرف الرئيسية (غرفة السفرة ... الخ) + 40 بالمائة من طلب التيار لكل نقطة إفادة أخرى.

* لغرض هذا الجدول، يحكم على سخان الماء بأنه سخان ماء بأي حمل إذا كان يسخن الماء فقط عندما يكون الصنبور مفتوحا ولذلك يستعمل الكهرباء بشكل متقطع.

\+ من المهم التأكد من أن لوحات التوزيع ووحدات المستهلك ذات مقرر كاف لاستيعاب الحمل الكلي الموصول معها دون تطبيق التشتت.